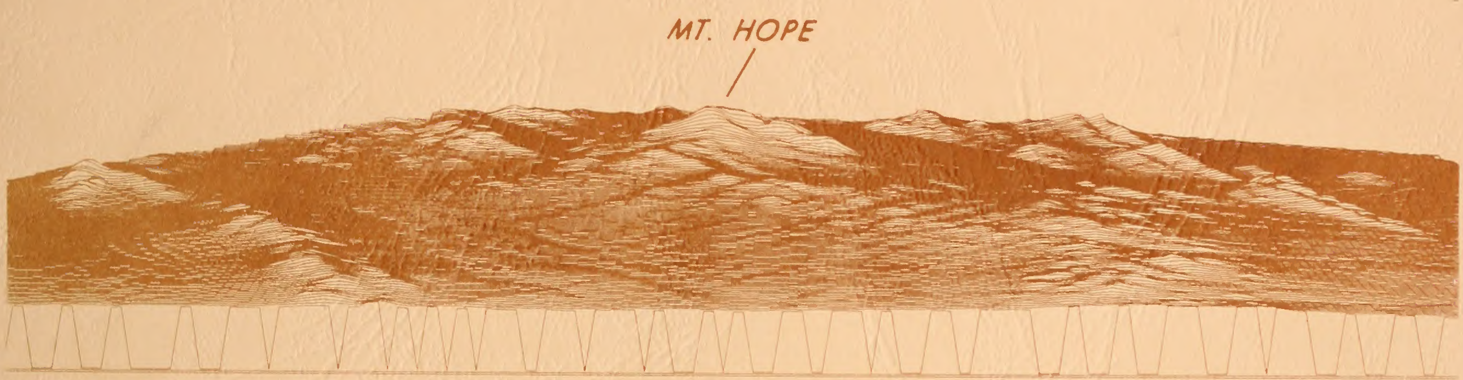
HYDROLOGY RESOURCES

TECHNICAL REPORT NO.4

MT. HOPE MOLYBDENUM PROJECT

VOLUME I OF II

TEXT



View from the south looking north

U.S. DEPARTMENT OF INTERIOR

BUREAU OF LAND MANAGEMENT

BATTLE MOUNTAIN, NEVADA

DECEMBER 1984

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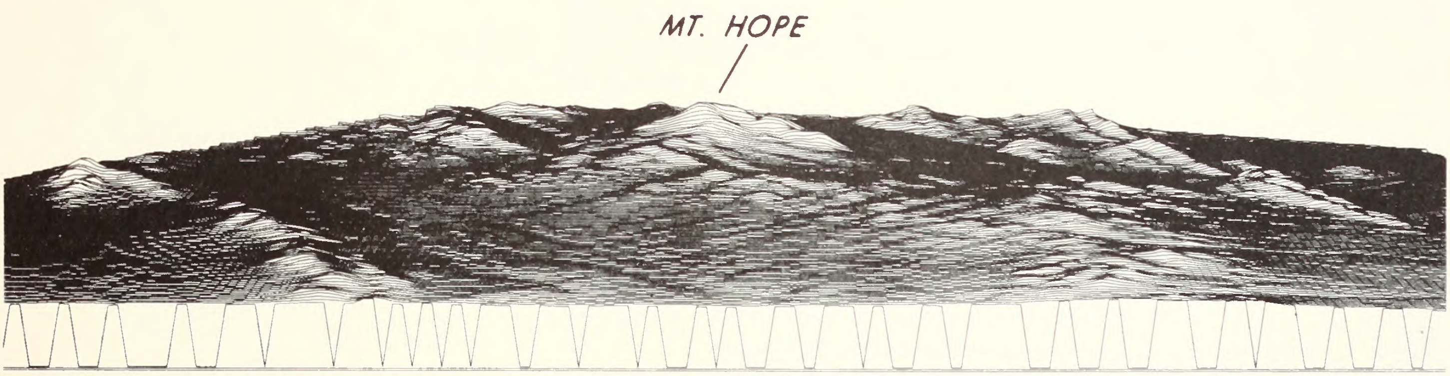

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U.S. DEPARTMENT OF INTERIOR

BUREAU OF LAND MANAGEMENT

BATTLE MOUNTAIN, NEVADA

DECEMBER 1984

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CHAPTER 1.0
INTRODUCTION

1.1 Introduction

This technical report presents detailed information concerning the hydrologic resource base (groundwater and surface water) and any significant potential impacts to that resource base upon implementation of the proposed action and/or alternatives.

1.2 Project Description

Technical Report No.1 and Chapter 2.0 of the Mt. Hope Molybdenum Project EIS detail the proposed action and alternatives. In brief, the Mt. Hope Molybdenum Project Environmental Impact Statement (EIS) (including Technical Report Nos.1 thru 9) have been prepared in response to an EXXON Minerals Company (EXXON) proposal submitted to the Bureau of Land Management (BLM) for the purchase of public lands under Section 203 of the Federal Land Policy and Management Act (FLPMA) of 1976. Although the land purchase proposal is the action which occasions the Environmental Impact Statement (EIS) process, there are other federal decisions which must be made before EXXON may proceed. Among these are the granting of power, water line and highway relocation rights-of-way and the approval of a plan-of-operation.

The primary purpose of the proposed sale of public lands involves the planned activities of EXXON which has for some time been conducting preliminary feasibility studies assessing the development of a molybdenum deposit in the vicinity of Mt. Hope near Eureka, Nevada. As part of the EIS process, EXXON has detailed its preliminary plans concerning project development. The Mt. Hope project includes the development of an open-pit mine, non-mineralized material storage areas (2), a process plant complex of approximately 100 acres and a tailings material disposal site. As support features to the project, a proposed water line and power line would also be necessary. The proposed tailings pond site would, if implemented, require an approximate six mile relocation of an existing state highway (State Route 278).

Figures 1-1 through 1-8 show project area location and depict the proposed action and alternatives (except the location of a subdivision plat). Table 1-1 outlines the components of the proposed action and alternatives, including the no action alternative.

1.3 Baseline Data Development

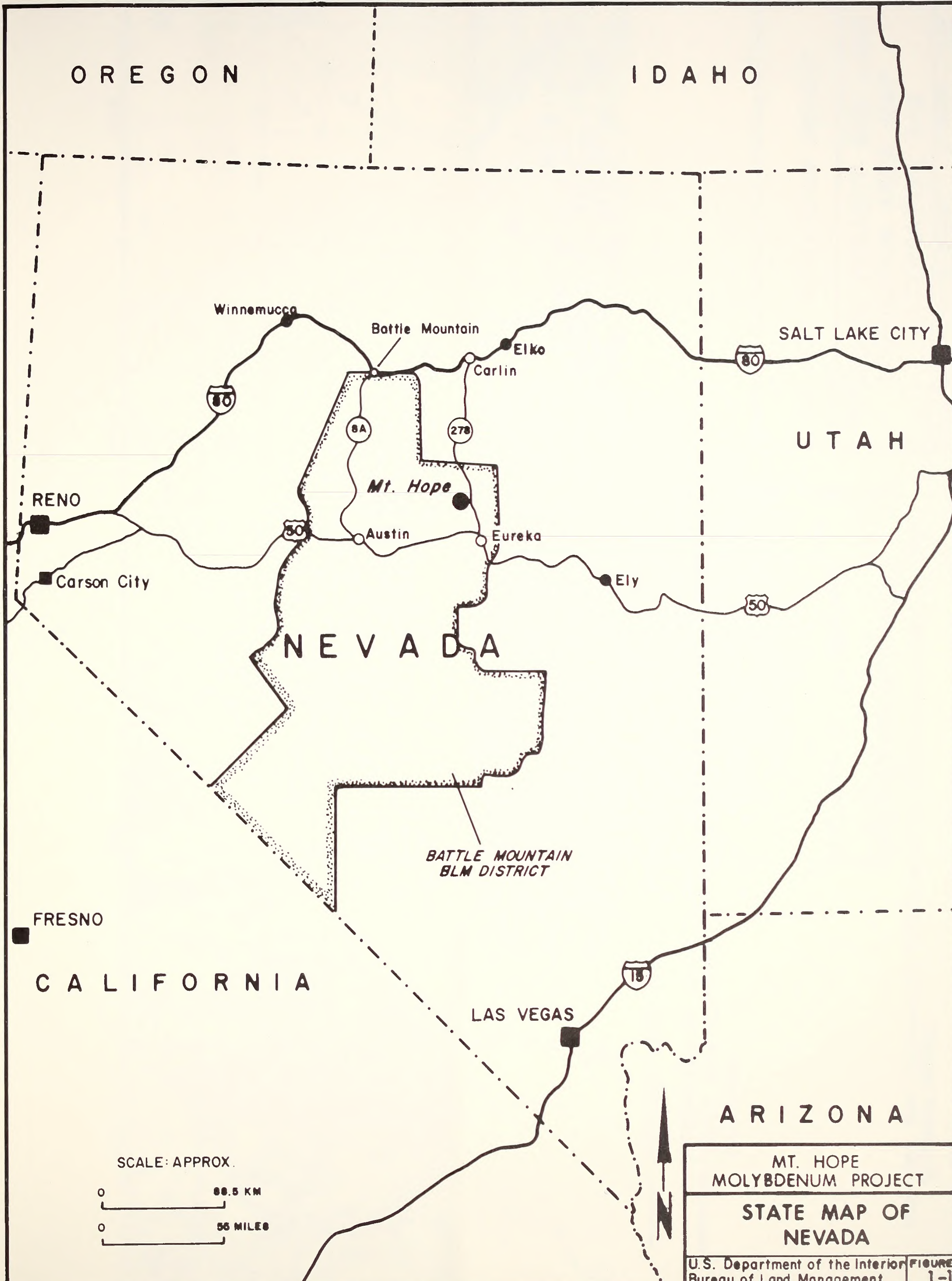
Early in the EIS process, the BLM and EXXON agreed in a Memorandum of Understanding (MOU) that the EIS process of data collection, analysis and documentation would be assisted by the involvement of an independent third party consultant, Wyatt Research and Consulting, Inc. (WRC). WRC initiated its involvement as an oversight quality assurance consultant in the development of a project source document for subsequent use in developing the Mt. Hope Molybdenum Project EIS. Entitled the Mt. Hope Molybdenum Project Environmental Impact Report (EIR), the source document included two chapters of information concerning environmental resources (baseline data and impact analyses) and prepared by WRC with assistance from the BLM and available study results of EXXON (e.g., cultural resources consultant report, geology, etc.). During the preparation of the source document and continuing throughout the EIS process, WRC has collected, reviewed and analyzed pertinent data in each of the necessary topical areas of environmental resources.

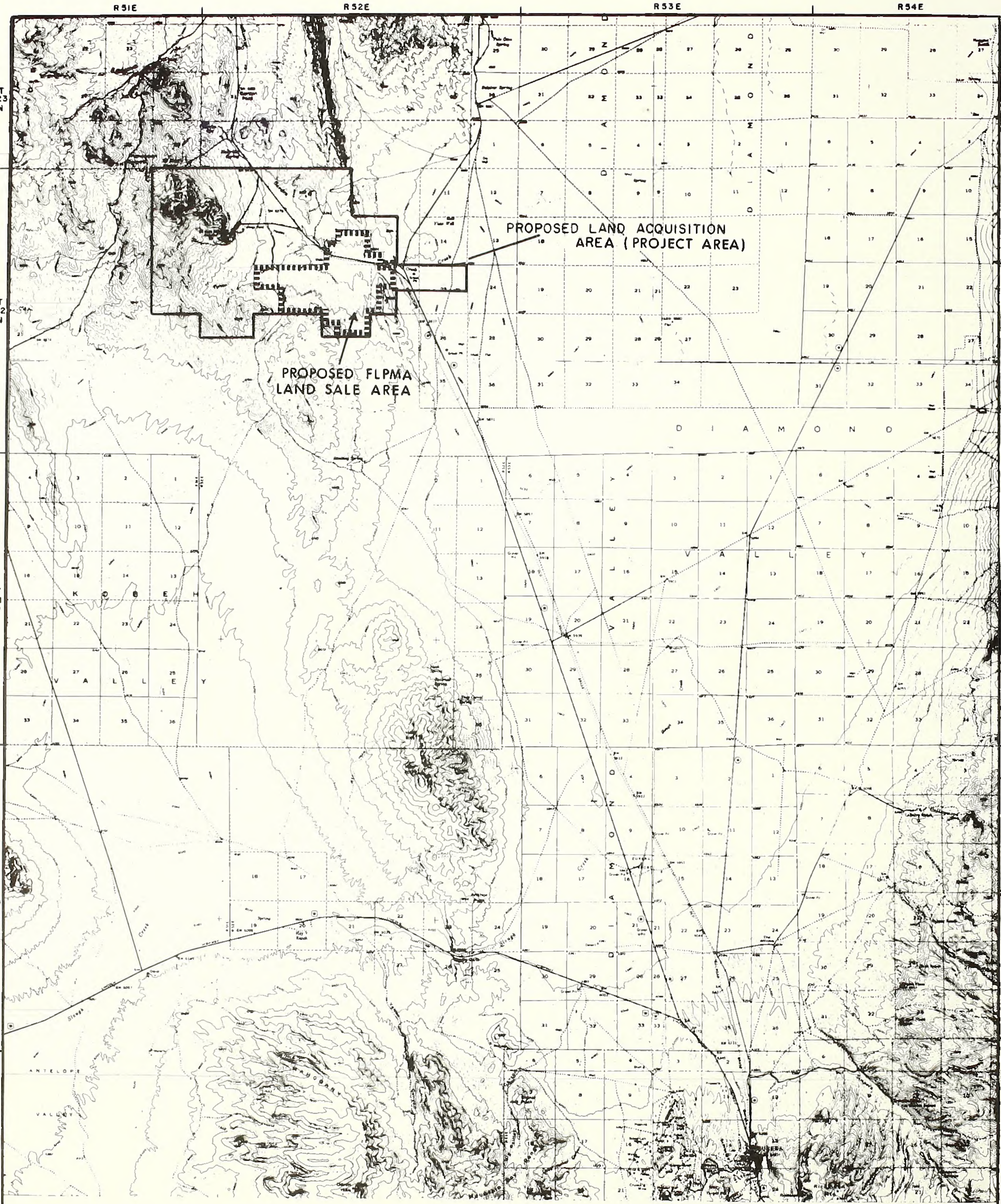
This technical report documents the majority of information gathered and analyzed that was pertinent to hydrologic resources. Hydro-Search, Inc. performed a Phase I and Phase II hydrology study for the Mt. Hope project during 1982 and 1983. The objectives of Phase I included:

1. Compilation, evaluation, and assessment of the adequacy of the existing hydrologic data base.

2. Provision of EXXON with "first evaluation" estimates for quantities of mine water inflow and the 100-year design storm runoff in the project area for the purpose of conceptual project planning.

3. Identification, preliminary evaluation, and priority ranking (based on existing data) of potential well fields for a long-term groundwater supply.


OREGON
IDAHO
Winnemucca
Battle Mountain
Elko
Carlin
SALT LAKE CITY
80
8A
278
UTAH
Mt. Hope
RENO
50
Austin
Eureka
Carson City
Ely
NEVADA
BATTLE MOUNTAIN
BLM DISTRICT
FRESNO
CALIFORNIA
15
LAS VEGAS
ARIZONA
N
SCALE: APPROX.
0
88.5 KM
0
55 MILES
MT. HOPE
MOLYBDENUM PROJECT
STATE MAP OF
NEVADA
U.S. Department of the Interior
Bureau of Land Management
FIGURE
1-1



——— PROPOSED LAND ACQUISITION AREA (PROJECT AREA)

▪▪▪▪▪▪▪▪ ESTIMATION OF APPROXIMATE FEDERAL LAND POLICY AND MANAGEMENT ACT (FLPMA) SALE AREA

Nevada MAP AREA

0 1 2 3 4 5 Miles

0 1 2 3 4 5 6 7 8 Km.

N

BASE: USGS TOPO QUADRANGLES, GARDEN VALLEY, WHISTLER MTN., DIAMOND SPRINGS & EUREKA, NEVADA

MT. HOPE MOLYBDENUM PROJECT

PROPOSED PROJECT AND LAND ACQUISITION AREA MAP ALTERNATIVE 1-A

U.S. Department of the Interior
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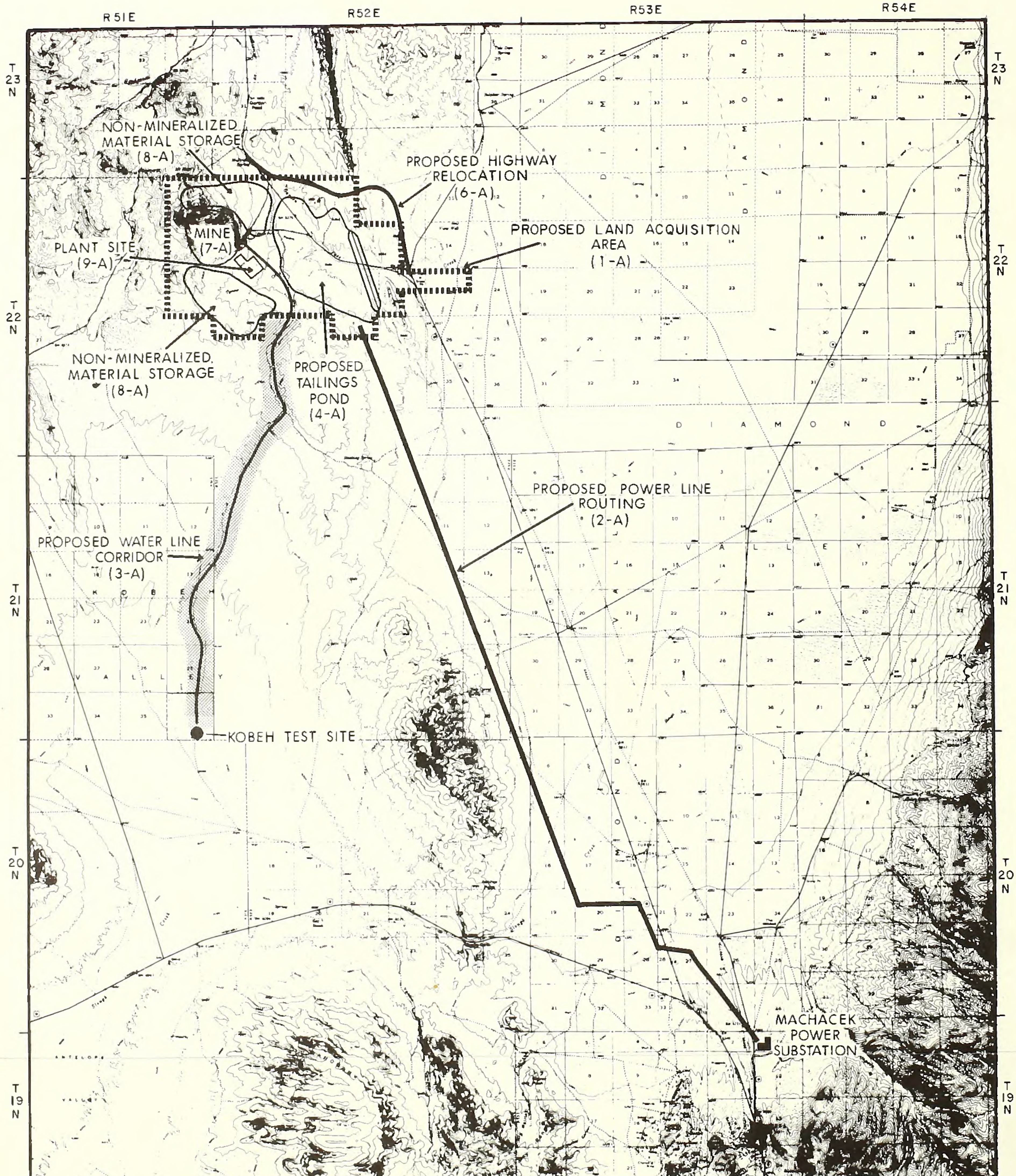
FIGURE 1-2



PROPOSED LAND ACQUISITION AREA BOUNDARY

*NOTE: COMPONENT 5-A (HOUSING SUBDIVISION) NOT SHOWN.
ALTERNATIVE 1-A (INCLUDING FLPMA LAND SALE AREA) SHOWN ON FIGURE 2-1.

0 1 2 3 4 5 Miles

0 1 2 3 4 5 6 7 8 Km.

Nevada MAP AREA

N

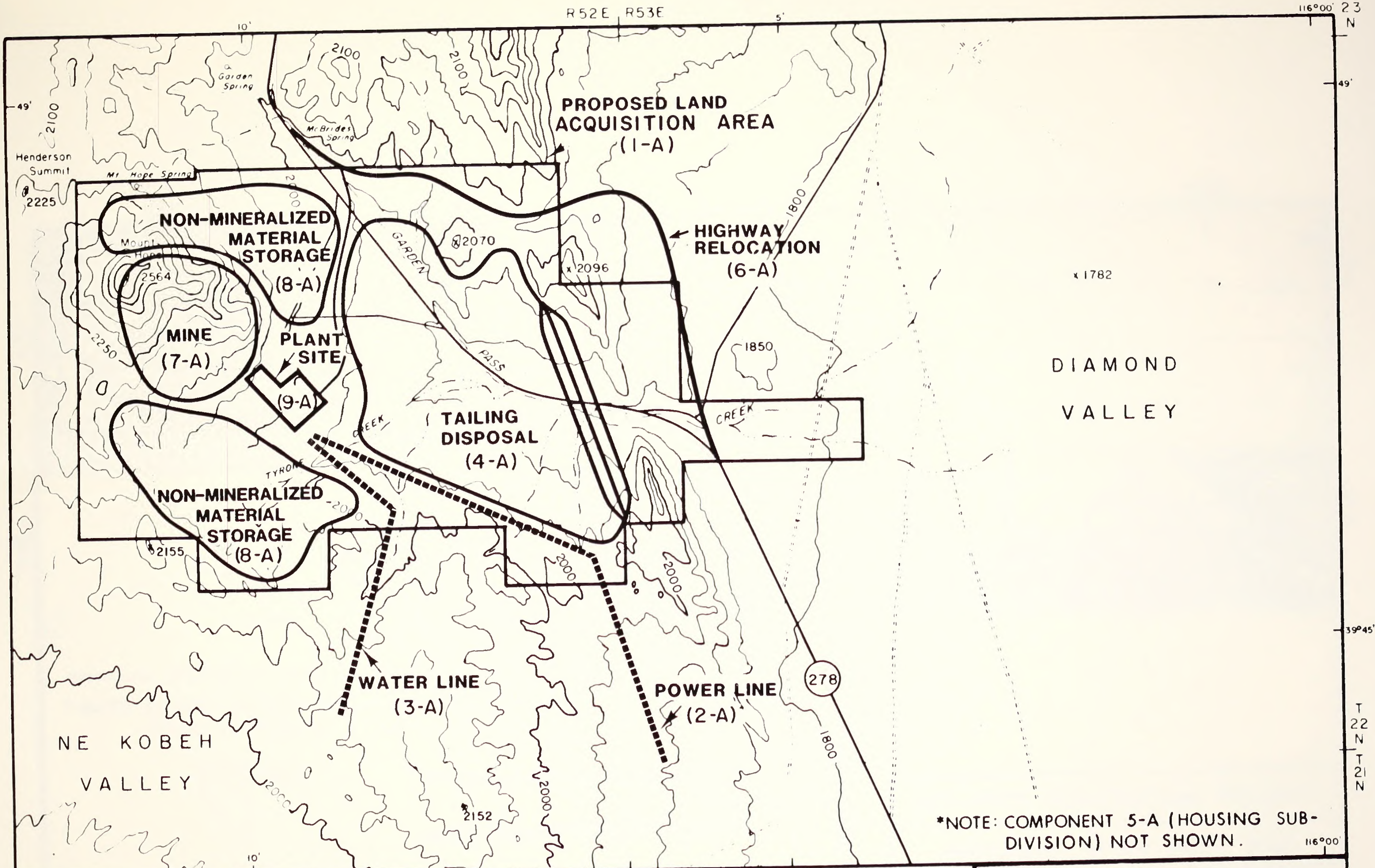
BASE: USGS TOPO QUADRANGLES, GARDEN VALLEY, WHISTLER MTN., DIAMOND SPRINGS & EUREKA, NEVADA.

MT. HOPE MOLYBDENUM PROJECT

REGIONAL STUDY AREA MAP SHOWING PROPOSED ACTION COMPONENTS

U.S. Department of the Interior
Bureau of Land Management

FIGURE 1-3

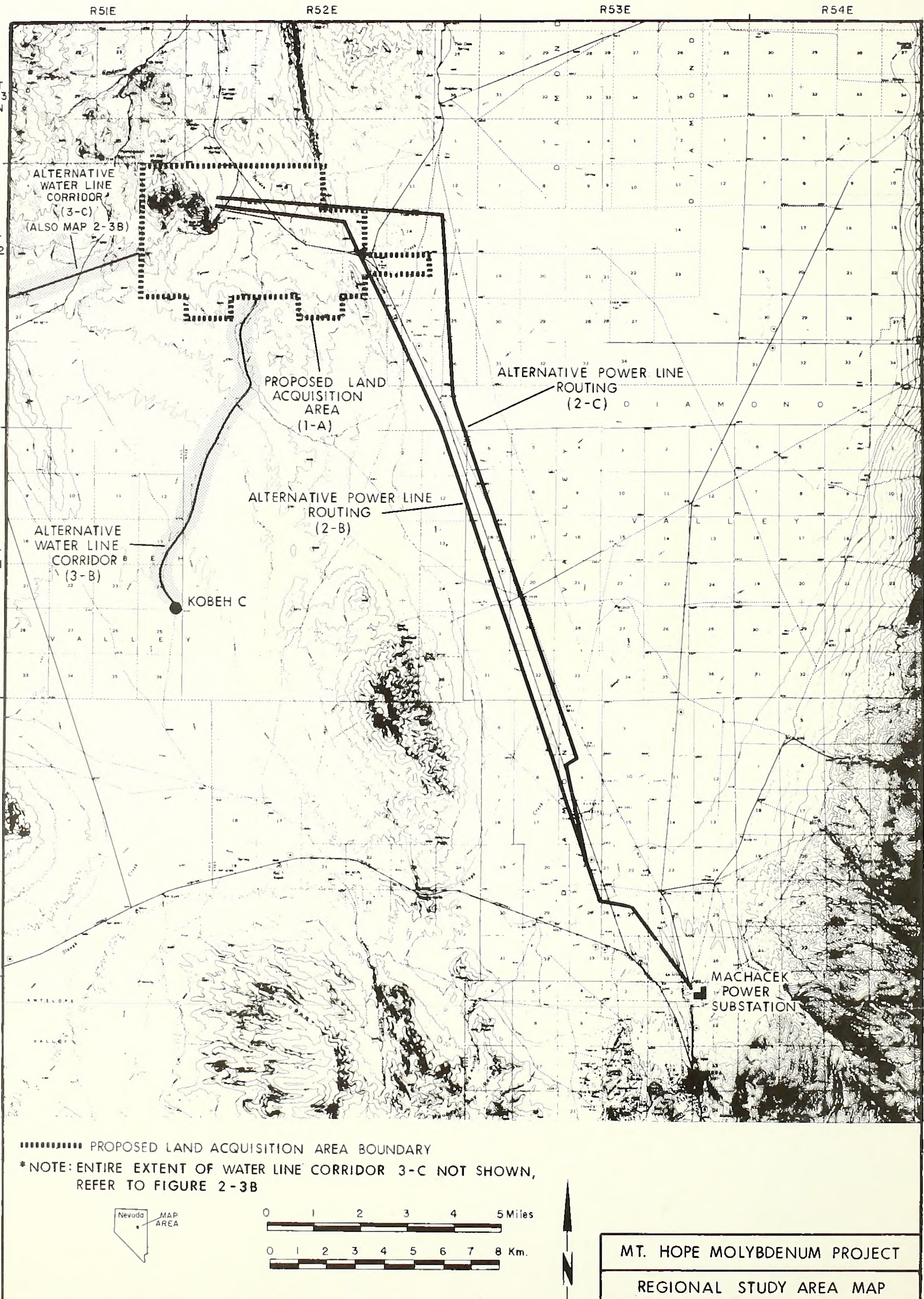


MT. HOPE MOLYBDENUM PROJECT

PROPOSED ACTION

U.S. Department of the Interior
Bureau of Land Management

FIGURE 1-4



PROPOSED LAND ACQUISITION AREA BOUNDARY

*NOTE: ENTIRE EXTENT OF WATER LINE CORRIDOR 3-C NOT SHOWN, REFER TO FIGURE 2-3B

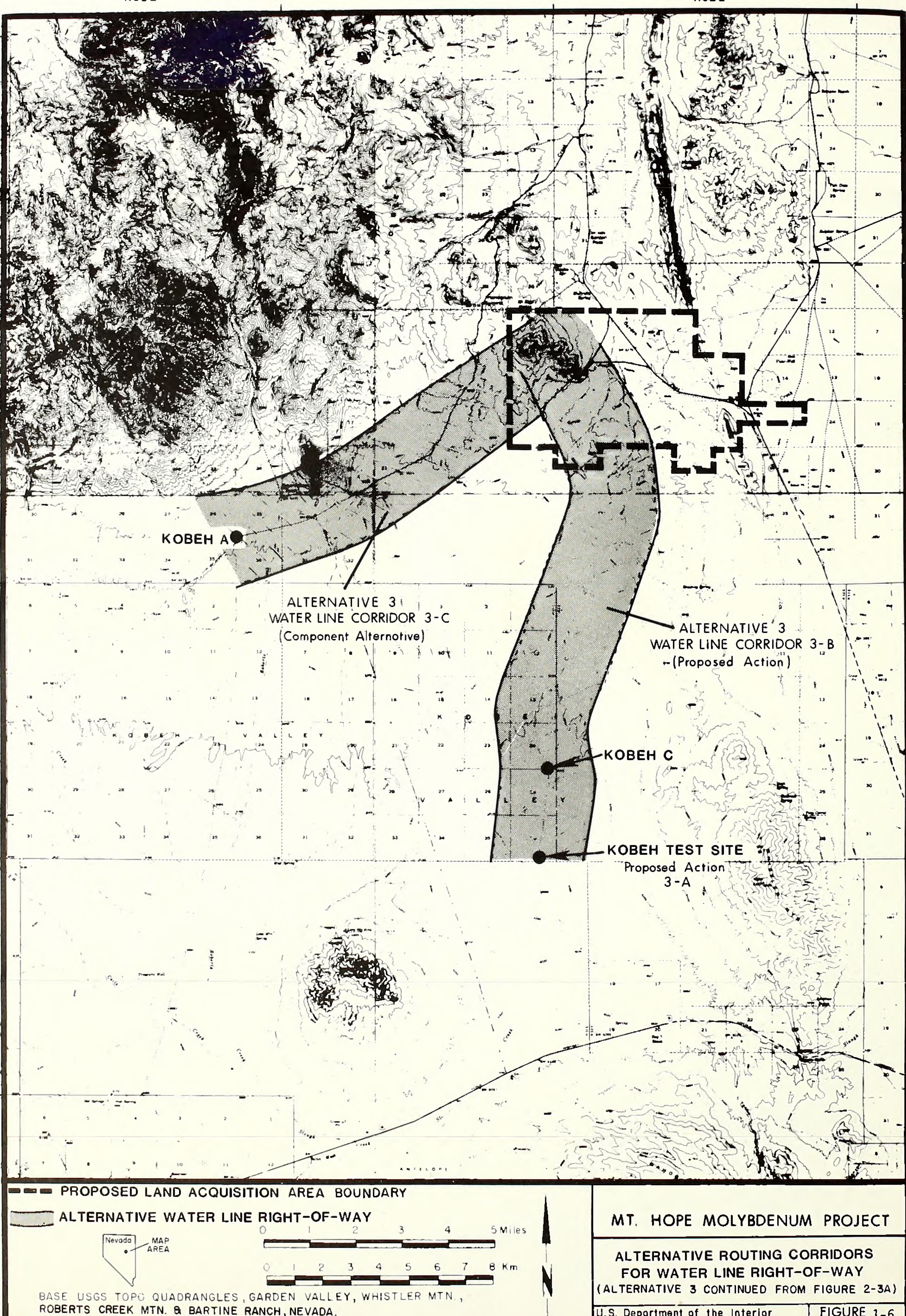
BASE: USGS TOPO QUADRANGLES, GARDEN VALLEY, WHISTLER MTN., DIAMOND SPRINGS & EUREKA, NEVADA.

MT. HOPE MOLYBDENUM PROJECT

REGIONAL STUDY AREA MAP SHOWING ALTERNATIVE COMPONENTS 2 AND 3 TO THE PROPOSED ACTION

U.S. Department of the Interior
Bureau of Land Management

FIGURE 1-5



MT. HOPE MOLYBDENUM PROJECT

ALTERNATIVE ROUTING CORRIDORS FOR WATER LINE RIGHT-OF-WAY
(ALTERNATIVE 3 CONTINUED FROM FIGURE 2-3A)

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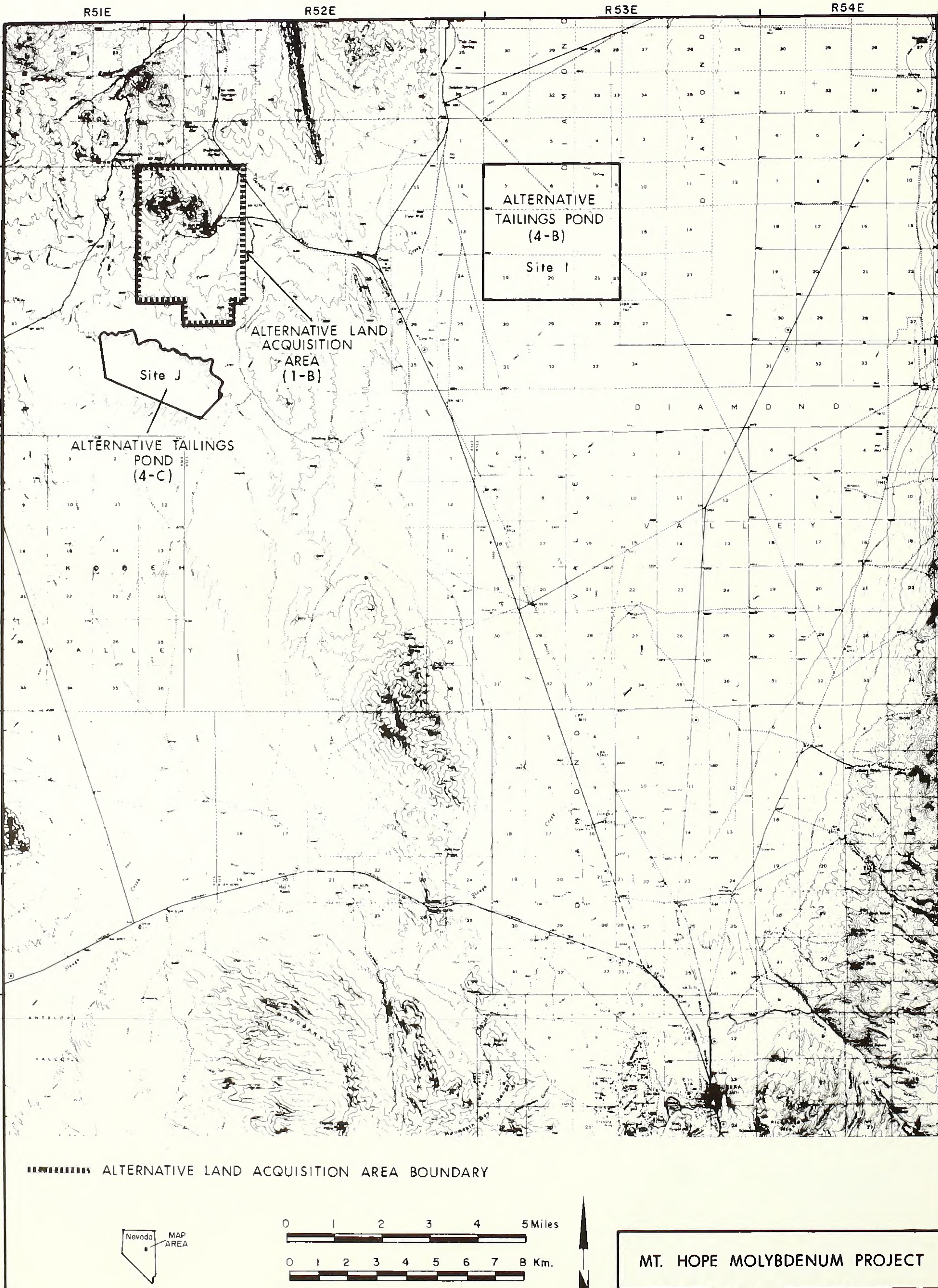
Bureau of Land Management

FIGURE 1-6



BASE: USGS TOPO QUADRANGLES, GARDEN VALLEY, WHISTLER MTN., DIAMOND SPRINGS & EUREKA, NEVADA.

MT. HOPE MOLYBDENUM PROJECT

REGIONAL STUDY AREA MAP SHOWING ALTERNATIVE COMPONENT 4 TO THE PROPOSED ACTION

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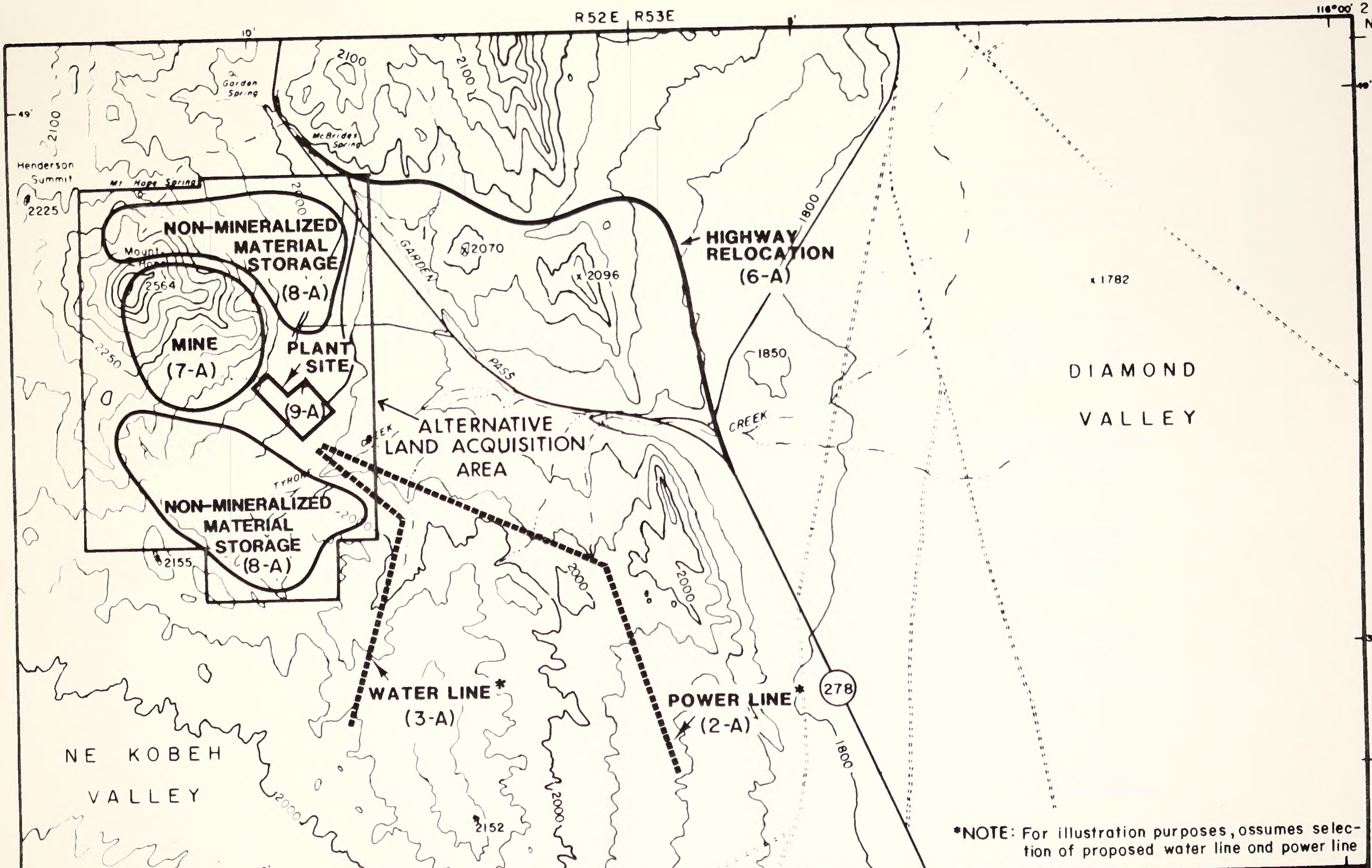
FIGURE 1-7



MT. HOPE MOLYBDENUM PROJECT

ALTERNATIVE LAND ACQUISITION AREA

U.S. Department of the Interior
Bureau of Land Management

FIGURE 1-8

Table 1-1 Summary Details of the Proposed Action and Alternatives Including the No Action Alternative

Proposed Action	Alternatives	No Action Alternative
	Alternative 1 - Land Acquisition Components	
1-A Land Sale by FLPMA	1-B Mineral Claims 1-C Land Use Lease 1-D Land Use Permit 1-E Land Exchange	Negative or no decision regarding land sale.
	Alternative 2 - Power Line Routing Components	
2-A Power Line Routing A (Figure 1-2)	2-B Alternative Routing 2-B (Figure 1-4) 2-C Alternative Routing 2-C (Figure 1-4)	No power line right-of way granted. Assumes the Mt. Hope Project will not proceed.
	Alternative 3 - Water Line Routing Components	
3-A Water Line Routing A (Figure 1-2)	3-B Alternative Routing 3-B (Figure 1-4) 3-C Alternative Routing 3-C (Figure 1-5)	No water line right-of-way granted. Assumes the Mt. Hope Project will not proceed.
	Alternative 4 - Tailings Pond Sites Components	
4-A Tailings Pond at Location 4-A (Figure 1-3)	4-B Alternative Site 4-B 4-C Alternative Site 4-C (Figure 1-4)	Not part of federal decision-making. Assumes no project implementation.
	Alternative 5 - Housing	
5-A Subdivision (Not shown on figure)	5-B Decentralized Workforce Housing (Not shown on figure)	Not part of federal decision-making. Assumes no project implementation.
	Alternative 6 - Highway Relocation Component	
6-A Highway Relocation Routing 6-A (Figure 1-3)	No reasonable alternatives available	No road relocation right-of-way granted.
	Alternative 7 - Mine	
7-A Mine at Location 7-A (Figure 1-3)	No reasonable alternatives available	Not part of federal decision-making. Assumes no project implementation.
	Alternative 8 - Non-Mineralized Material Storage Areas	
8-A Non-Mineralized Material Storage at Location 8-A (Figure 1-3)	No reasonable alternatives available	Not part of federal decision-making. Assumes no project implementation.
	Alternative 9 - Process Plant	
9-A Process Plant at Location 9-A (Figure 1-3)	No alternatives proposed. (Proposed action is worst-case. See text).	Not part of federal decision-making. Assumes no project implementation.

4. Formulation of recommendations for expanding the hydrologic data base and refinement of the above three project hydrologic factors (mine water inflows, runoff, groundwater supply) by means of field and office studies during subsequent phases of the project.

The objectives of Phase II included:

1. Field reconnaissance for collection of surface water data to update and refine calculations of 100-year storm runoff predictions.

2. Locate wells, measure water levels, and construct a groundwater level contour map within a 10-mile radius of Mt. Hope to verify Phase I conclusions on the groundwater flow regime in the project area.

3. Drill a series of exploration wells in Kobeh Valley to select a suitable site for construction of a test well and perform an aquifer test.

4. Construct and test pump a test well to provide aquifer parameters (i.e., transmissivity and storage coefficient) for the alluvial aquifer in the vicinity of Kobeh "C" wellfield.

5. Determine the feasibility of installing a 5,000 gpm wellfield at Kobeh "C" wellfield.

The primary sources of other hydrologic resource information included the following:

1. Call and Nicholas, Inc. 1982. "Mt. Hope Pre-Mine Slope Design." Prepared for Exxon Minerals Company, Inc.

2. Eakin, T. E., 1961. Ground-Water Appraisal of Pine Valley, Eureka dn Elko Counties, Nevada. Ground-Water Resources Reconnaissance Series Report 6, Nevada Department of Conservation and Natural Resources.

3. Eakin, T. E., 1962. Ground-Water Appraisal of Diamond Valley, Eureka and Elko Counties, Nevada. Ground-Water Resources Reconnaissance Series Report 6, Nevada Department of Conservation and Natural Resources.

4. Eakin, T. E. et al., 1951. Contributions to the Hydrology of Eastern Nevada. Water Resources Bulletin 12, Nevada Department of Water Resources.

5. Harrill, J. R., and Lamke, R. D., 1968. Hydrologic Response to Irrigation Pumping in Diamond Valley, Eureka and Elko Counties, Nevada, 1950-1965. Water Resources Bulletin 35, Nevada Department aof Conservation and Natural Resources.

6. Hydro-Search, Inc., 1982. Mt. Hope Project, Phase I Hydrology. Volumes I and II, for Exxon Minerals Company, Houston, Texas.

7. Hydro-Search, Inc., 1983. Mt. Hope Project, Phase II Hydrology, for Exxon Minerals Company, Houston, Texas.

8. Roberts, R. J., Montgomery, K. M., and Lehner, R. E., 1967. Geology and Mineral Resources of Eureka County, Nevada. Bulletin 64, Nevada Bureau of Mines and Geology.

9. Rush, F. E., and Everett, D. E., 1964. Ground-Water Appraisal of Monitor, Antelope, and Kobeh Valleys, Nevada. Ground-Water Resources Reconnaissance Series, Report 30, Nevada Department of Conservation and Natural Resources.

10. Williams, J. R., 1975. HYMO Flood Routing, Journal of Hydrology, No. 26, pp. 17-25.

11. Williams, J. R., and R. W. Hann, Jr., 1972. HYMO: Problem-Oriented Computer Language for Hydrologic Modeling, Agricultural Research Service, U.S. Department of Agriculture.

1.4 Impact Analyses Methodology

In the case of any discrepancies between this technical report and the EIS, the material presented in the EIS shall supercede that which is presented in this technical report.

1.4.1 Determination of Flood Plain

In order to determine the potential for and location of flood plain areas in the Mt. Hope vicinity, design storm runoff, peak discharges and total volume of runoff were estimated for watersheds near Mt. Hope. Existing information obtained for the investigation came from the Soil Conservation Service (SCS), U.S. Geological Survey (USGS) and the U.S. Bureau of Land Management (BLM). The existing data were verified by Hydro-Search, Inc., who also incorporated new input data and improvements to the SCS rainfall-runoff calculation methodology.

A field reconnaissance of surface water hydrology was performed by Hydro-Search, Inc. for verification and refinement of the input data throughout the area. The work included:

1. location and inspection of principal stream channels to determine stream type, estimate annual flow regimes, and observe high-water marks and other evidence of historical flooding,

2. location and inspection of USGS crest-stage gages and characterization of the associated stream channel control sections,

3. observation of soils and vegetative cover and density to verify or improve site-specific watershed parameters used for Phase II SCS runoff estimates, and

4. measurement of channel cross sections and longitudinal gradients of the principal drainage courses at significant locations for input to storm runoff routing calculations.

Improvement to design storm runoff and flood routing estimates were also made. This entailed the surveying of eleven stream channel cross sections at the outlets of major watersheds and sub-watersheds. The 100-year, 6-hour and 24-hour storms were used as design precipitation events.

All data were then entered into HYMO, a rainfall-runoff computer model developed by the Agricultural Research Service, USDA (Williams and Hann, 1972), which estimates storm runoff, peak discharge and total discharge from a design storm. HYMO also performed flood-routing calculations based on the Variable Travel Time (VTT) method (Williams, 1975) for routing storm runoff using channel geometries and lengths of stream reaches. For more detailed information on 100-year design storm runoff calculations, refer to Appendix 4-F.

1.4.2 Determination of Mine Pit Inflows

Mine pit inflow analysis is based upon the current five-year and final conceptual mine plans as provided by EXXON for determination of lateral and vertical inflow and fault and fracture zone inflow.

The estimates are of passive inflows to the open pit, being characterized as inflows which would occur without any prior or concurrent alteration (e.g., dewatering puming) of the existing groundwater conditions. Estimation of these inflows is limited to the amount of information available regarding hydraulic parameters, water levels, and hydraulic potential of the wall rocks, location and hydrologic characteristics of heterogeneities in the wall rocks, and location and type of hydrologic boundaries. The estimates assume instantaneous imposition of the truncated inverse cone of the pit at the various pit stages of 5-, 14-, and 20-years. (Hydro-Search, Inc., 1982).

For lateral inflow the pit is modeled as a fully-penetrating, large-diameter cylindrical well. Lateral radial flow into the pit can be estimated using the analogy between inflow to a pit where the water level is maintained at a constant level (pit floor) and the rate at which water would have to be pumped to maintain constant drawdown in a very large diameter well (Hydro-Search, Inc., 1982). The inflow equations are for the nonsteady state in

which time is a variable and discharge decreases with time. The Jacob-Lohman equation (Lohman, 1972) for nonsteady radial flow without vertical movement to a cylindrical well under constant drawdown was used to estimate lateral inflow (see Appendix 4-G).

The conditions for vertical inflow assumes flow through a vertical cylinder from the Eastern Assemblage carbonates to the pit floor. Vertical upward inflow to the pit bottoms can be estimated by the Darcy equation for steady flow through a vertical right cylinder of igneous rocks and Vinini hornfels under a constant gradient in hydrualic head (see Appendix 4-G).

Estimates were also made for several sample cases of inflow from major tabular faults and fracture zones under conditions which might be met during open pit mining. Two cases were used for estimation:

1. vertical pervious zone in igneous and hornfels wall rocks, and

2. vertical pervious zone connected to underlying Eastern Assemblage rocks.

Case 1 calculations are based upon the Stallman equation (Lohman, 1972) and Case 2 calculations are based upon the Darcy equation which assumes vertical upward inflow to the pit bottom.

1.4.3 Determination of Tailings Pond Seepage Characteristics

Prediction of pond seepage is technically difficult and there exist uncertainties about geological and groundwater conditions at the alternative pond sites. Some data are available for the geological conditions underlying the ponds and general present direction of groundwater movement beneath them.

Maximum and minimum seepage rates were estimated for the lake area and overflow slime area assuming a set of physical conditions to exist using material properties determined in the laboratory for the steady state condition by applying Darcy's Law.

Calculation of the seepage rate after reclamation involved a three-step process: (1) calculation of total volume of water remaining in the tailings, and (2) calculating the percentage of total water that would be retained in the tailings, and (3) calculation of amount of time it will require that finite unstored volume to seep from the tailings pond.

1.4.4 Determination of Groundwater Withdrawal Effects

The potential well fields were evaluated for drawdown effects upon the existing aquifer. Existing data on perennial yield for Kobeh, Diamond and Garden valleys was used. Perennial yield is the maximum amount of water which can be withdrawn from the groundwater reservoir and used economically each year for an indefinite period of time (Rush and Everett, 1964).

Two different pumping schemes were used by Hydro-Search, Inc. during the Phase I hydrology study for potential well field drawdown:

Case 1. This case includes 4 wells pumping 1350 gpm (85.2 lps) for 20 years. These conditions were selected to simulate drawdowns over the projected life of the mine.

Case 2. This case includes 2 wells pumping 2700 gpm (170.4 lps) for 6 months. These conditions were selected to represent the "worst case" in any given year from producing 5400 gpm (340.7 lps) any two of the four wells from each well field.

Assumptions made for drawdown projections were as follows:

1. The aquifer is infinite, homogeneous, and confined.
2. Drawdown is accompanied by instantaneous release of water from storage.
3. There is no recharge to the aquifer during the period that the wells are pumping and the aquifer is receiving no leakage from the confining aquitard.
4. The wells start pumping simultaneously and the pumping rate for all wells is equal.

CHAPTER 2.0

BASELINE HYDROLOGY DESCRIPTION

2.1 Regional Hydrology

East-central Nevada is hydrologically characterized by an arid climate regime, basins commonly having internal drainage and limited surface water. Precipitation occurs from frontal storms during winter and as thunderstorms during summer. The frontal storms are generally low intensity, long duration events covering large areas with much of the precipitation in the form of snow. Thunderstorms are generally high intensity, short duration events of limited areal extent.

Streams are generally of an intermittent or ephemeral nature. Very few perennial streams occur in the valleys. Perennial mountain streams do occur, but only flow for a limited distance. Most streamflow is in direct response to rainfall and melting snow, creating a seasonal variation to the streamflow due to precipitation and temperature.

Although the region is deficient of surface water, large volumes of water are stored in valley groundwater reservoirs (Eakin, Price and Harril, 1976). An understanding of the mechanisms involved to produce this condition can be envisioned by knowledge of the hydrologic cycle within the region, as illustrated in Figure 2-1. Precipitation runoff and streamflow in the mountainous areas rapidly descends toward the lower elevations and valleys. As runoff crosses the alluvial deposits of the valleys, most of it quickly infiltrates downward into this material and becomes part of the groundwater system. The Nevada Department of Water Resources (1971) reports an average loss of 1.0 cfs per mile downstream. This figure is adequate to absorb nearly all mountain runoff produced in a normal year. The remaining runoff is generally restricted to channel flow across the alluvial plain and is discharged onto the playa of the valley floor, where it ponds and rapidly evaporates. Depending on local geologic conditions and groundwater flow, some of the water which has infiltrated into the alluvial material is discharged down-gradient from the fans in the form of seeps and springs, commonly associated with fault zones (see Figure 2-2).

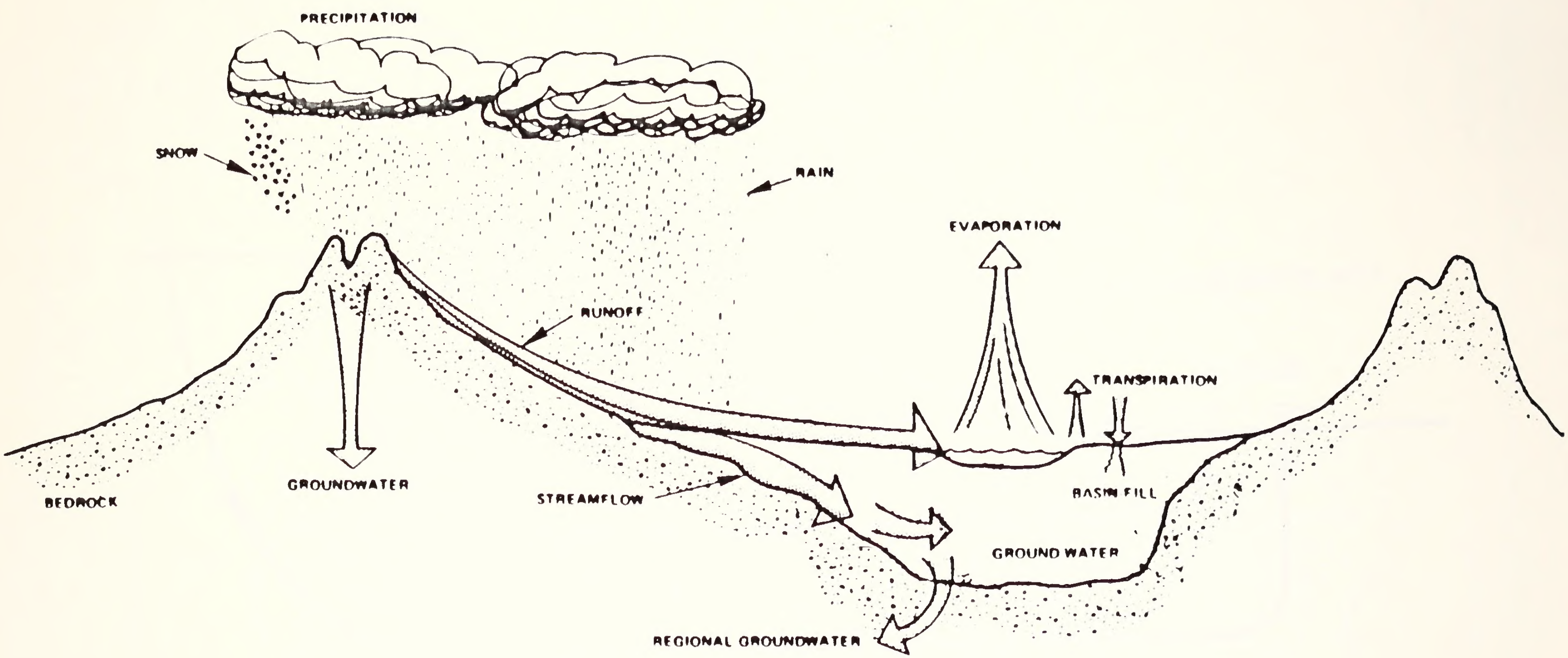


FIGURE 2-1 The hydrologic cycle.

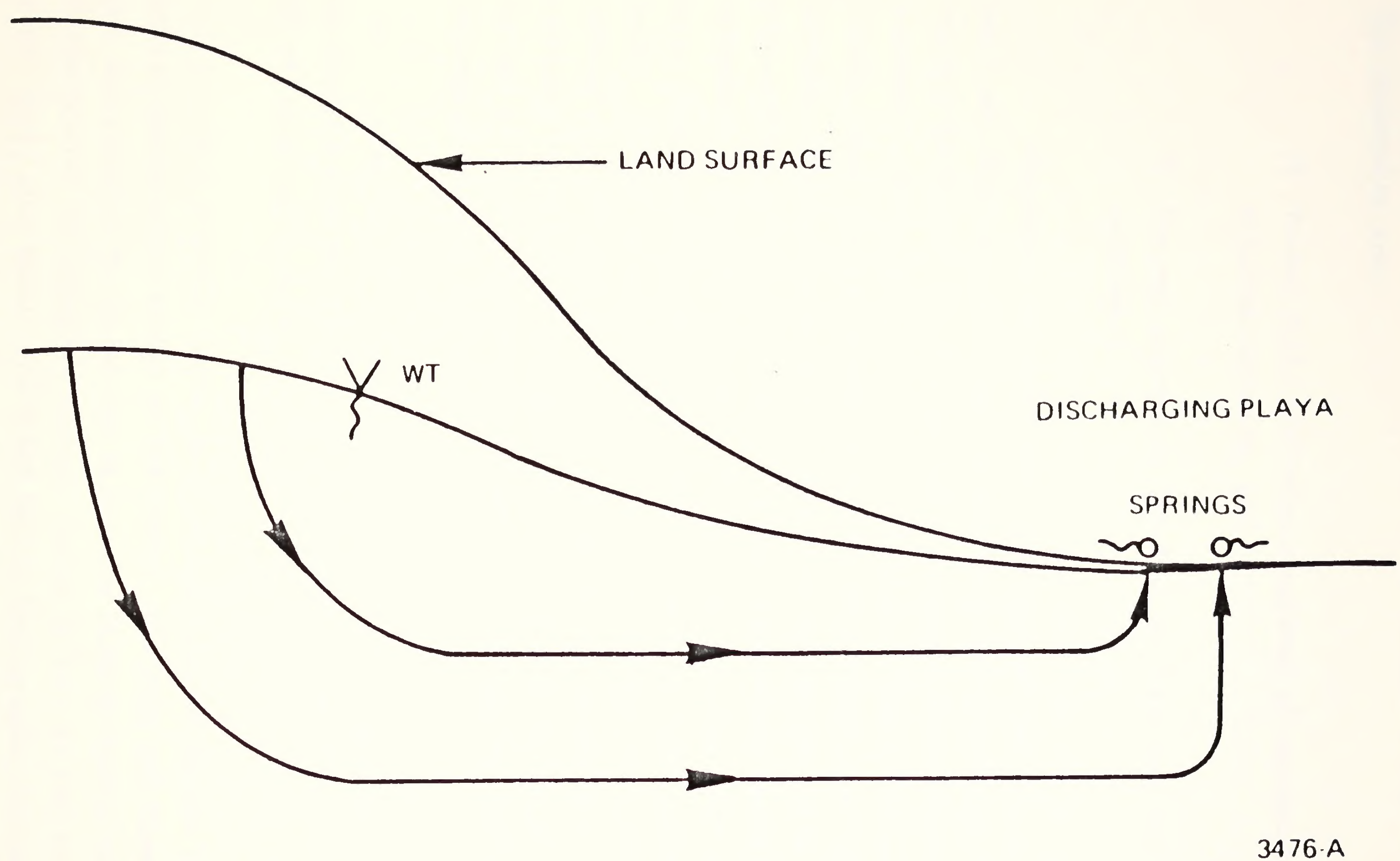


FIGURE 2-2 Idealized groundwater flow system for drainage basin in the Great Basin (from Maxey, 1968).

The Nevada Department of Water Resources has identified two distinct types of groundwater reservoirs as being characteristic of east-central Nevada. The reservoirs are:

1) Valley fill reservoirs comprised of unconsolidated alluvial deposits, and

2) Bedrock reservoirs typified by fractured Paleozoic carbonates.

Paleozoic carbonate rocks underlie much of the region to considerable depth and also outcrop in many of the surrounding mountain ranges. Several valleys are known to be hydraulically connected via this underlying carbonate reservoir. Henningson, Durham and Richardson (HDR, 1980) noted from Eakin (1966), "that the valley-fill aquifers, when viewed on a regional scale, resemble isolated aquifers separated laterally by the thick sequences of Paleozoic carbonates and, in places, Tertiary volcanics. Extensive zones within the carbonates are highly permeable (in places even cavernous) and may transfer water from areas of higher elevation to areas of lower elevation. Little is known, however, about the rate at which groundwater is transmitted through the carbonate aquifer and how it is related to the 'isolated' valley-fill aquifers. Although the estimated average regional transmissibility is 200,000 gallons per day per ft., (a transmissivity of about 27,000 sq. ft. per day), the local transmissivity may vary widely."

The relationship between the basin and range faulting (north-south), the distribution of springs, and the communication between the carbonate and the alluvial aquifers is not fully understood (HDR, 1980).

On a regional basis, much of east-central Nevada falls within the Central Hydrographic Region of the State. Mt. Hope and Diamond Valley (located east and south of Mt. Hope) lie within the Diamond Valley Hydrographic Subbasin of the Central Hydrographic Region. Kobeh Valley, to the south and southwest of Mt. Hope, lies within the Kobeh Valley Hydrographic Subbasin, also of the Central Hydrographic Region. Garden/Pine valleys, to the north and west of Mt. Hope, lie within the Pine Valley Hydrographic Subbasin of the Humboldt River

Basin. Hydrographic basins and subbasins are illustrated in Figure 2-3.

2.1.1 Regional Hydrogeology

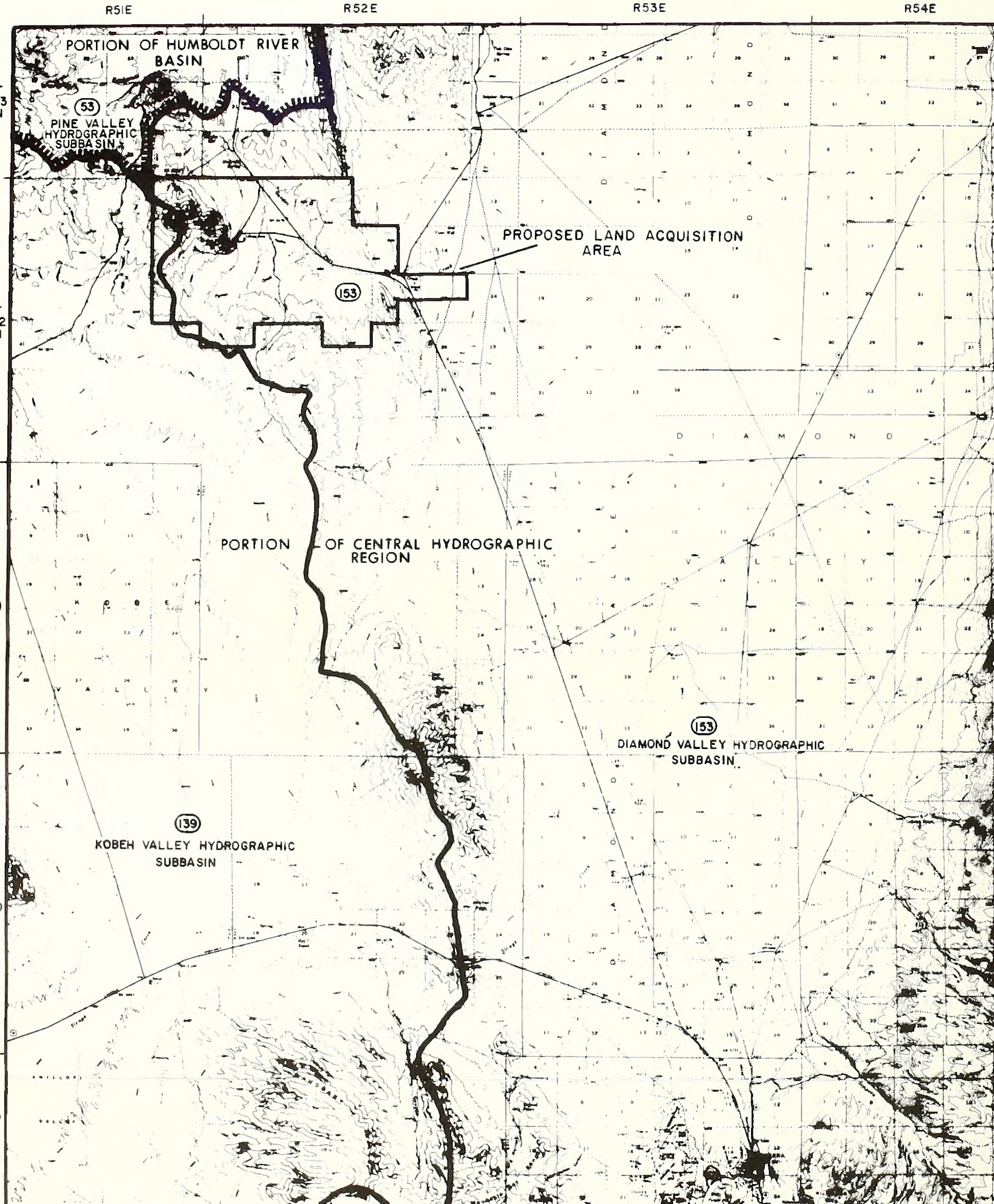
This section has, except for editing, been taken directly from the work performed by Hydro-Search, Inc. (1982) for EXXON, entitled "Mt. Hope Project Phase I Hydrology, Vol. 1".

The Roberts Mountains and the surrounding ranges and valleys lie in the central part of the Great Basin section of the Basin and Range physiographic province. The area is characterized by block faulting which results in a roughly north-south trending topography. The major ranges in the area are the Roberts Mountains, Simpson Park Range, Sulphur Spring Range, Diamond Mountain and the Cortez Mountains. Most of these ranges follow a north-south linear trend, except for the Cortez and Simpson Park Mountains which have northeast trending segments. Of the interlying basins, both Diamond and Pine Valleys are elongated in a north-south direction, whereas Kobeh Valley is roughly equidimensional in form.

The Mt. Hope mine site is located in the southeastern part of the Roberts Mountains of east-central Nevada. The regional area of hydrologic concern is defined by a circle having a 25-mile radius surrounding Mt. Hope (see Figure 2-4). Previous geological work in this area includes Merriam (1940), Merriam and Anderson (1942), Roberts, et al (1958), Roberts, et al (1967) and Stewart (1980). Maps of the area include a geologic map by Roberts (1967) and a regional gravity survey compiled by Mabey (1964). Regional geology is depicted in Figure 2-4.

As shown in Figure 2-5, rocks ranging in age from Cambrian to Recent are exposed in the Roberts Mountains, surrounding ranges and adjacent valleys. The following discussion presents a generalized summary of the various lithologic units, after which the structural relationships of these units are described.

Eastern Assemblage Rocks (EA). The term "Eastern Assemblage", as referred to herein, includes a number of formations ranging from the Cambrian age Prospect



PROPOSED LAND ACQUISITION AREA BOUNDARY

REGIONAL HYDROGRAPHIC BOUNDARY

AQCR BOUNDARY & HYDROGRAPHIC SUB-BASIN BOUNDARY

HYDROGRAPHIC SUB-BASINS

(53) PINE VALLEY

(139) KOBEH VALLEY

(153) DIAMOND VALLEY

BASE: USGS TOPO QUADRANGLES, GARDEN VALLEY, WHISTLER MTN., DIAMOND SPRINGS & EUREKA, NEVADA.

Nevada MAP AREA

N

0 1 2 3 4 5 Miles

0 1 2 3 4 5 6 7 8 Km.

MT. HOPE MOLYBDENUM PROJECT

HYDROGRAPHIC BASINS AND SUBBASINS

U.S. Department of the Interior
Bureau of Land Management

FIGURE 2-3

OVERSIZE DRAWING

(Enclosed in Volume II)

FIGURE 2-4

GENERALIZED REGIONAL GEOLOGY

Age	Formation	Assemblage	Western Assemblage (WA)
Quaternary-Tertiary	Alluvium (QTa) (includes alluvial, colluvial, lacustrine, and eolian deposits)		
Tertiary	Igneous Complex (Ti) (intrusive and volcanics)		
	UNCONFORMITY		
Permian	Garden Valley Formation	Overlap Assemblage (OA)	
Pennsylvanian or Permian(?)	Brock Canyon Formation	Overlap Assemblage (OA)	
Pennsylvanian	Ely Limestone	Overlap Assemblage (OA)	
Mississippian	Diamond Peak Formation	Overlap Assemblage (OA)	
	Chainman Shale	Overlap Assemblage (OA)	
	Pilot Shale (ANTLER OROGENY)	Eastern Assemblage (EA)	Western Assemblage (WA)
Devonian	Devils Gate Limestone	Eastern Assemblage (EA)	
	Nevada Formation	Eastern Assemblage (EA)	
Silurian	Lone Mountain Dolomite	Eastern Assemblage (EA)	Undifferentiated Sediments not present in Mt. Hope area.
	Roberts Mountains Formation	Eastern Assemblage (EA)	
Ordovician	Hanson Creek Formation	Eastern Assemblage (EA)	
	Eureka Quartzite	Eastern Assemblage (EA)	Vinini and Valmy Formations
	Pogonip Group	Eastern Assemblage (EA)	
Cambrian	Windfall Formation	Eastern Assemblage (EA)	
	Dunderberg Shale	Eastern Assemblage (EA)	
	Hamburg Dolomite	Eastern Assemblage (EA)	
	Secret Canyon Shale	Eastern Assemblage (EA)	
	Geddes Limestone	Eastern Assemblage (EA)	
	Eldorado Dolomite	Eastern Assemblage (EA)	
	Pioche Shale	Eastern Assemblage (EA)	
	Prospect Mountain Quartzite	Eastern Assemblage (EA)	

Source: Modified from Roberts, Montgomery and Lehner (1967).

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STRATIGRAPHY OF THE MT. HOPE REGION

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FIGURE 2-5

Mountain Quartzite to the Pilot Shale of Early Mississippian age. It is not necessary to identify these units separately for purposes of the hydrologic evaluation because the bulk of the rock units exhibit similar hydrogeological characteristics and can be considered a single unit.

The dominant rocks of the Eastern Assemblage are limestone and dolomite, with minor amounts of shale and quartzite. They were deposited in a shallow-water, miogeosynclinal environment which covered eastern Nevada and western Utah (Stewart, 1980). In the Eureka area, Roberts (1967) estimated the thickness of the Eastern Assemblage to be about 14,500 feet, 90 percent of which is composed of carbonate material. In the Roberts Mountains, Eastern Assemblage carbonates are exposed as windows in the overlying Roberts Mountain thrust plate. Lone Mountain, located in Kobeh Valley south of the Roberts Mountains, is composed almost entirely of Eastern Assemblage carbonates. Additional exposures occur to the southeast and also along the western margin of Diamond Valley, due either to faulting or other structural features (see Figure 2-4).

The Devonian carbonates (part of the Eastern Assemblage) are not exposed in the Mt. Hope (ed.) vicinity but occur at distance in all directions from the site and probably exist at depth below the site (see Figure 2-4). The principal rocks comprising this hydrogeologic group are the Nevada Formation (limestone and dolomite) and Devils Gate Limestone which were deposited in a shallow marine environment. EXXON exploration records indicate that drill hole EMH-3 intersected a skarn at approximately 4,690 feet elevation that may be altered Eastern Assemblage rocks.

Western Assemblage Rocks (WA). During the Paleozoic Era, a thick sequence of siliceous sediments and volcanic rocks were deposited in a deep-water, eugeosynclinal environment. These rocks are referred to as "Western Assemblage", and include the Ordovician Vinini and Valmy Formations, as well as a group of younger, undivided, sedimentary rocks (Roberts, 1958 and 1967). Although Roberts (1958) estimated the Western Assemblage to be in excess of 50,000 feet thick, the sequence is probably much thinner in the Roberts Mountains area due to thrusting, uplift and erosion. Near the proposed mine site, exploration

holes drilled by EXXON to depths greater than 2,600 feet have not fully penetrated the Western Assemblage. Therefore, at present, the exact thickness remains unknown.

The Western Assemblage rocks consist mainly of shale, siliceous shale, chert, quartzite and siltstone with minor amounts of limestone and andesitic volcanic rocks which range in age from Ordovician to Late Devonian (Roberts, 1967). In the Roberts Mountains area, the Western Assemblage is represented entirely by the Ordovician Vinini Formation, which forms the basal unit of the Roberts Mountains thrust plate. The Vinini Formation exposed in the mine area was deposited in a deep marine environment and is composed of a basal unit of silty argillite, shale and chert and a middle unit of shale with sandstone lenses, argillite and chert. The sandstone lenses are commonly calcareous. The middle unit comprises most of the Vinini Formation at the mine site. The upper Vinini is primarily chert and calcareous argillite and not of widespread occurrence in the mine area.

Overlap Assemblage Rocks (OA). During the Late Devonian and Early Mississippian Antler orogeny, uplift, folding, faulting and erosion occurred in western Nevada (Roberts, 1967). During this period, rocks of the Western Assemblage were displaced eastward and southeastward over the Eastern Assemblage by a major, low-angle thrust fault known as the Roberts Mountain Thrust (Stewart, 1980). Based on the distribution of Western Assemblage rocks overlying Eastern Assemblage rocks, Roberts (1958) suggested the total movement of the upper thrust plate to have been approximately 90 miles. Rocks both above and below the fault were deformed during thrusting. The highland created by the orogeny shed coarse detrital sediments eastward. At the easternmost extent of this deposition, the finer clastics interfinger with the normal marine sequence. Along the orogenic belt, the clastics overlie folded and faulted preorogenic rocks of both Western and Eastern Assemblages (Roberts, 1967). As such, these rocks have been termed the "Overlap Assemblage".

The Overlap Assemblage in the Eureka area consists of six formations that exhibit a composite thickness of approximately 13,000 feet which range in age from Mississippian to Permian (Roberts, 1967). These are, in ascending

order, the Chainman Shale, Diamond Peak Formation, Ely Limestone, Brock Canyon Formation and the correlative Carbon Ridge and Garden Valley Formations (Roberts, 1967). Major rock types of the Overlap Assemblage include conglomerate, sandstone, shale, siltstone, claystone and limestone.

In the Sulphur Spring Range, east of Mt. Hope, the Overlap Assemblage consists entirely of Garden Valley Formation. These rocks form an abrupt north-south trending ridge east of Mt. Hope. Four members of the formation have been recognized in this area (Roberts, 1967). They are, in ascending order, a limestone member (500 feet), a conglomerate member (1,000 feet), a highly resistant, ridge-forming, siliceous conglomerate member (1,000 feet) and a shale member (550 feet). A small outcrop of the basal unit of this formation occurs southeast of Mt. Hope. This outcrop lies unconformably between the younger Tertiary igneous rocks and the older Vinini Formation at the southeast corner of the site. This lower unit is primarily shallow water limestone altered to skarn due to contact metamorphism by the Mt. Hope intrusive. The skarn is the host rock for the ore mined from the original Mt. Hope Mine. Other exposures of Overlap Assemblage rocks occur at Devils Gate, in the Simpson Park Range and in the Diamond Mountains (see Figure 2-4).

Tertiary Igneous Rocks (Ti). Tertiary volcanic and intrusive rocks crop out extensively in the Roberts Mountains and surrounding areas. Extrusive rocks in the Roberts Mountains include rhyolitic tuffs and breccias, andesitic flows and thick flows of quartz latite (Merriam and Anderson, 1942). In Garden Valley, Table Mountain is composed of olivine basalt flows which were mapped as Tertiary Age by Merriam and Anderson (1942).

The Tertiary Period was characterized by multiple intrusive episodes which formed the Mt. Hope igneous complex and ore deposit (Westra, 1980). These episodes caused extensive fracturing, shearing and faulting of the igneous rocks and the country rock. Large scale landslides possibly related to caldera subsidence may have occurred along several arc-shaped normal faults that occur in the vicinity of the site. The most prominent of these features are the Mt. Hope and Ravine Faults.

Chemical and thermal activity related to the Tertiary intrusive has

affected most of the igneous rocks and surrounding portions of the Vinini Formation altering the latter to hornfels near the margins of intrusive rocks. Beyond this hornfels "rim", the Vinini Formation is presumed to be relatively fresh and extends laterally, relatively uninterrupted for several miles from the mine site.

Valley Fill Alluvium (Quaternary-Tertiary Alluvium, QTa). With the exception of northern Pine Valley, the valley fill of the three major basins in the study area, Kobeh, Diamond, and Garden/Pine, has not been extensively studied. The valley fill can be divided into two major units, older and younger alluvium. For the purposes of this report all unconsolidated to semiconsolidated valley fill material is referred to as QTa.

The older alluvial fans or pediment surfaces were probably formed during the Late Tertiary and early Pleistocene time following major uplift (Roberts, 1967). These fans consist of unconsolidated to poorly consolidated, poorly sorted gravel, sand and silt. The younger alluvium is late Pleistocene and Recent in age, and ranges from poorly sorted sands and gravels to fine-grained lacustrine sediments and playa deposits.

In Kobeh and Garden-Pine Valleys, the younger alluvium is confined largely to present-day stream channels. However, in Diamond Valley the entire valley floor is covered by younger alluvium. The northern part of Diamond Valley is covered by a large playa deposit dominated by saline silts and clays (Roberts, 1967).

The thickness of the valley fill has been determined largely by interpretation of gravity data (Mabey, 1964) and by sparse drill hole information. The western part of Kobeh Valley contains about 5,000 feet of fill which appears to thin markedly toward the east. Diamond Valley, at its deepest point in the east-central portion of the valley, contains about 7,500 feet of sediments. The southern portion of Pine Valley contains about 5,000 feet of fill, but the thickness increases rapidly toward the central part of the valley to approximately 10,000 feet.

2.1.2 Regional Groundwater System

The regional groundwater system was studied in order to determine the groundwater flow systems in Kobeh, Diamond and Garden/Pine valleys, the geologic formations or units responsible for groundwater movement and production, and the evaluation of possible well field locations and drawdown. Because surface water is so scarce in the region, it would not supply the required 5,400 gpm for the mill process and potable water. Therefore, the projected water requirements would be derived from water wells tapping into the groundwater system. The studies were performed by Hydro-Search, Inc. (1982) and are given verbatim in the following sections (Sections 2.1.2.1 and 2.1.2.2).

2.1.2.1 Hydraulic Characteristics of Geologic Materials (Hydro-Search, Inc., 1982-1983)

The characteristics of the five major geologic units present in the vicinity of the proposed mine and mill complex that are pertinent to the production of groundwater are summarized in Table 2-1. Of the five units, only the Quaternary-Tertiary alluvium (QTa) has sufficient primary permeability to store and transmit important quantities of groundwater. The undifferentiated Paleozoic Eastern Assemblage carbonate rocks (EA) and portions of the undifferentiated Paleozoic Overlap Assemblage rocks (OA) are of considerable thickness and probably have developed sufficient secondary permeability due to faulting and solution activity to transmit and yield major quantities of water. Minor, secondary permeability exists in other units (Western Assemblage and Tertiary Igneous rocks), but these are not considered major water producing units.

Valley Fill Alluvium (QTa). Well logs show the alluvium to consist of interstratified sands, gravels, and clays. The top of the saturated zone is relatively shallow in the valley floors and the alluvium is one of the better potential aquifers in the area. Although gravity data have shown the alluvium in western Kobeh Valley to be on the order of 5,000 feet (1,525 m) thick, in the areas of potential well fields the thickness ranges from about 300 feet (91.5 m) to 1,000 feet (305 m). The deepest portions of Diamond and Pine Valleys are underlain by about 7,500 feet (2287.5 m) and 10,000 feet (3050 m) of alluvium, respectively. Approximately 600 feet (183 m) of alluvium are estimated in the

Table 2-1 Summary of Characteristics of Geologic Materials

Geologic Unit	Age	Lithologic Description	Maximum Thickness feet (m)	Estimated Rating: Primary Permeability	Estimated Rating: Secondary Permeability
Alluvium	Tertiary-Quarternary (QTa)	Poor to well sorted clays, sands, and gravels; inter-mixed and interbedded.	5,000 (Kobeh) 1/ (1525 m) 7,500 (Diamond) 2/ (2287.5 m) 10,000 (Pine) 2/ (3050 m)	Good to Excellent	
Igneous Rocks	Tertiary (Ti)	Undifferentiated flows, tuffs, breccias, plugs and stocks.	2,000 3/ (610 m)	Poor, locally could be Fair	Poor, locally could be Fair
Overlap Assemblage (Garden Valley Fm.-carbonate member)	Paleozoic (OA)	Dominantly limestone with some calcareous sandstone, chert-pebble congolmerate, and cherty limestone beds.	500 4/ (152.5 m)	Poor	Poor 5/
Eastern Assemblage (carbonates)	Paleozoic (EA)	Dominantly limestone and dolomite with minor amounts of shale and quartzite.	14,500 4/ (4422.5 m)	Poor	Good to Excellent
Western Assemblage (Vinini Formation)	Paleozoic (WA)	Dominantly shale, siliceous, shale, chert, quartzite, siltstone with minor lime-stone and andesitic volcanic rocks.	Unknown	Poor	Poor, locally could be Fair

1/ Thickness estimated from gravity data.
2/ Thickness determined from drill hole information
3/ Thickness estimated from cross section of Merriam and Anderson (1942).
4/ Thickness estimated by Roberts (1967).
5/ Overall secondary permeability is considered low because only the lower part of the Garden Valley Formation consists of carbonates.

Source: Hydro-Search, Inc. 1982

vicinity of a former potential well field 1/ in Diamond Valley (Diamond "A" well field, see Figure 2-4). The alluvial thickness of about 400 feet (122 m) is projected for one of the former potential well fields in Garden Valley near the mine site (Garden "A"). The alluvium in Garden/Pine Valleys thickens gradually to the north where a thickness of about 5,000 feet (1,525 m) or more occurs in the vicinity of the former potential Garden "C" well field (see Figure 2-4).

Depths of existing wells in all three basins are generally less than about 400 feet (122 m). Some pumping rates are given for a few Diamond Valley wells; however, no formal step drawdown or constant discharge aquifer test data are available. Therefore, it is necessary to estimate aquifer coefficients for the valley fill alluvium. Table 2-2 lists aquifer parameters calculated from aquifer test data obtained by Hydro-Search, Inc. (HSI) for similar alluvial basins in Nevada and Utah. Using these figures and what is known about the geology and productivity of the basins, aquifer coefficients are estimated as indicated on Table 2-3.

The estimated transmissivity (T) value for Kobeh "B" well field is lower than the other three well fields. Transmissivity, as calculated above, is a product of saturated thickness penetrated by the well and the hydraulic conductivity. Because the Kobeh "B" well field is situated closer to the source area for the alluvial materials, it is reasonable to assume the alluvium would be poorly sorted. The other three alluvial well fields are located further from source areas, where the alluvium would probably exhibit a greater degree of sorting and stratification. As such, a reasonable value for the hydraulic conductivity at Kobeh "B" would probably be lower than that for either the Diamond "A", Garden "B" or Garden "C" well fields. The Diamond "A" well field

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1/ Prior to completion of hydrologic studies and the conditional granting of water rights in Kobeh Valley, EXXON had also applied for water rights in Pine/Garden and Diamond Valley. EXXON has agreed to drop these previously filed applications and would develop a well field in Kobeh Valley. Discussion herein concerning Pine/Garden and Diamond Valleys is presented only to allow an understanding of area hydrology.

Table 2-2 Estimated Aquifer Characteristics of Alluvial Materials in Other Basin and Range Hydrographic Basins

Basin	Saturated Thickness (feet)	Hydraulic Conductivity (K)(gpd/ft^2)	Transmissivity (T)(gpd/ft)	Storage Coefficient (S)	Comments	Source
Big Smoky Valley, Nevada	215 (65.6 m)	246 (10.0 m/d)	52,800 (654.7 m^2/d)	---	Aquifer test, 800 gpm (50.5 lps), no observation wells, well depth - 803' (244.9 m), SWL 588' (179.3 m), alluvial fan material.	HSI, aquifer test, Tonopah, Feb.-Mar. 1975
Big Smoky Valley, Nevaka	593 (180.9 m)	208 (8.5 m/d)	87,700 (1087.5 m^2/d)	3.5×10^{-3}	Aquifer test 2340 gpm (147.6 lps), well depth = 1015' (309.6 m), alluvial fan material.	HSI aquifer test, Tonopah January 1980
Antelope Valley, Nevada	500 (152.5 m)	800 (32.6 m/d)	400,000 (4960.0 m^2/d)	1.0×10^{-1}	Aquifer test 1000 gpm (63.1 lpa), well depth = 902' (275.1 m), SWL 1181' (360.2 m), sand and gravel alluvium, small percentage of fines.	HSI aquifer test, Elko County, Nov. 1974
Mason Valley, Nevada	390 (118.6 m)	500 (20.4 m/d)	192,000 (2380.8 m^2/d)	---	Aquifer test 2000 gpm (126.2 lps), no observation wells, well depth = 400' (122.0 m), SWL = 10' (3.1 m), Valley alluvium.	Circle Bar Ranch, Yerington, Nov. 1981
Pine Valley, Utah	605 (184.5 m) 1622 (494.7 m) 830 (253.2 m) 488 (148.8 m)	116 (4.7 m/d) 57 (2.3 m/d) 98 (4.0 m/d) 37 (1.5 m/d)	70,000 (1140.8 m^2/d) 92,000 (1140.8 m^2/d) 81,000 (1004.0 m^2/d) 18,000 (223.2 m^2/d)	8×10^{-4} 2×10^{-3} 1×10^{-3} 6×10^{-2}	Based on limited aquifer test data from records of Utah State Engineer's Office, wells about 1000' (305.0 m) deep in alluvium.	HSI analysis of pump test data on file with the Utah State Engineer's Office.

Table 2-3 Aquifer Coefficients for Proposed Alluvial Well Fields

Well Field	Saturated Thickness in Well(b)(ft)	Hydraulic Conductivity (K)(gpd/ft^2)	Transmissivity* (T)(gpd/ft)	Storage Coefficient (S)
Kobeh "B"	850 (259.1 m)	200 (8.2 m/d)	170,000 (2108 m^2/d)	0.01
Diamond "A"	350 (106.8 m)	750 (30.5 m/d)	262,500 (3255 m^2/d)	0.1
Garden "B"	400 (122 m)	500 (20.4 m/d)	200,000 (2480 m^2/d)	0.01
Garden "C"	400 (122 m)	500 (20.4 m/d)	200,000 (2480 m^2/d)	0.01

* T = bK

Source: Hydro-Search, Inc., 1982

is assigned the highest estimated hydraulic conductivity, because existing groundwater development in Diamond Valley has shown, at least in a general way, good potential for development of highly productive wells.

Storage coefficients in the range of 0.1 to 0.01 were assigned to the alluvium. The value 0.1 (specific yield) was assigned to Diamond "A" well field because unconfined conditions are likely to exist at that locality. The other alluvial well fields are likely to exhibit a mixed confined and unconfined condition due to the stratified nature of the individual producing zones. An intermediate storage coefficient of 0.01 was assigned to these well fields.

Eastern Assemblage (EA) Carbonate Rocks. Although the primary permeability of these rocks probably is low, the carbonates have a relatively high secondary permeability due to solution openings and fracturing. That these rocks do in fact transmit water is shown by Shipley Hot Spring which discharges water from carbonate rocks on the eastern flank of the Sulphur Spring Range. Although this spring apparently discharges through alluvium, Harrill and Lamke (1968) point out that the spring is probably supplied by deeply circulating groundwater, which passes from bedrock through the alluvium to be discharged at the surface. Shipley Hot Spring discharges an estimated 4,900 acre-feet/year (ac-ft/yr) (3,038 gpm) of water (Harrill and Lamke, 1968).

No wells are known to have been completed in the carbonate rocks in this area so it is necessary to estimate hydraulic coefficients. Hydraulic conductivity will vary considerably depending upon the degree to which secondary openings are developed. A reasonable range in values is 400 to 2,000 gpd/ft^2 (16.3 to 81.4 m/d). Values can be substantially higher in zones of cavernous solution openings, but these zones usually are a maximum of tens of feet in thickness. The value of hydraulic conductivity used in Table 2-4 is at the lower end of the range.

Transmissivity values can be estimated using the product of thickness of producing section in section in feet and the hydraulic conductivity.

A reasonable estimate of storage coefficient (S) for these rocks under unconfined to partially confined conditions is 0.01. However, at both

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Table 2-4 Aquifer Coefficients for Proposed Eastern Assemblage Well Fields

Well Field	Saturated Thickness in Well(b)(ft)	Hydraulic Conductivity (K)(gpd/ft^2)	Transmissivity (T)(gpd/ft)	Storage Coefficient (S)
Kobeh "A"	500 (152.5 m)	500 (20.4 m/d)	250,000 (3100.0 m^2/d)	0.01
Kobeh "C"	500 (152.5 m)	500 (20.4 m/d)	250,000 (3100.0 m^2/d)	0.01
Diamond "B"	500 (152.5 m)	500 (20.4 m/d)	250,000 (3100.0 m^2/d)	0.01
Diamond "C"	500 (152.5 m)	500 (20.4 m/d)	250,000 (3100.0 m^2/d)	0.0005
Garden "A"	500 (152.5 m)	500 (20.4 m/d)	250,000 (3100.0 m^2/d)	0.0005

Source: Hydro-Search, Inc., 1982

the Diamond "C" and Garden "A" well fields, the Eastern Assemblage carbonates are probably confined. In this case, the storage coefficient may be estimated as the product of thickness of producing section in feet and the factor of 1 x 10^{-6} feet $^{-1}$ (Lohman, 1972).

Estimated aquifer coefficients for the proposed well fields completed in Eastern Assemblage carbonates are listed in Table 2-4.

Although the lower part of the Garden Valley Formation of the Overlap Assemblage (OA) is comprised of carbonate rocks and produces water locally via solution openings and fractures, it is not considered a major potential water source. However, this is based on limited geological and hydrological data because few wells are constructed in these rocks in the Mt. Hope area.

Western Assemblage Rocks (WA) and Tertiary Igneous Rocks (TI). These rocks have essentially negligible primary permeability and probably only poor to fair secondary permeability. The extent to which secondary permeability is developed is dependent on the degree of fracturing of the rocks. The Western Assemblage acts as a regional aquiclude, restricting flow of groundwater and acting as a confining layer over the deeply buried Eastern Assemblage carbonates.

Although these rocks are not completely impervious and will transmit some groundwater, in terms of water supply, the volume transmitted through these rocks is relatively unimportant.

Under certain circumstances, the occurrence and structural attitide of the Western Assemblage rocks may affect a well field producing water from the Eastern Assemblage. Such may be the case at the Kobeh "A" well field where the downfaulted Western Assemblage could act as an impervious boundary east of the well field.

From a regional standpoint, hydraulic coefficients of these rocks are not important. In the case of mine-water inflows, however, such parameters are more significant and are discussed in Section 3.4.

2.1.2.2 Regional Groundwater Flow System (Hydro-Search, Inc., 1982-1983)

The generalized regional groundwater flow system has been summarized on Figure 2-6. Shown on this map are water levels for individual wells, contours of equal water level elevation and generalized directions of groundwater movement. Well records used in constructing this map are summarized in Appendix 4-A.

Kobeh Valley. In general, groundwater movement in the alluvium of Kobeh Valley follows the direction of surface flow. Recharge from the surrounding mountains moves toward the valley floor and then continues eastward toward Devils Gate. Precipitation in the Roberts Mountains is a major source for recharge to the aquifers in Kobeh Valley.

From the contours of equal water level elevation on Figure 2-6, the hydraulic gradient indicates the general west to east movement toward Diamond Valley where groundwater occurs at an elevation of about 5,900 feet (1,799.5 m). At Devils Gate, however, the alluvial cover is relatively thin and the pass is so narrow that eastward movement of groundwater through the alluvium is restricted. This is substantiated by a small playa that has formed just west of the Devils Gate area. Water levels in the valley floor are very near the surface (approximately five feet (1.5 m) below the surface) and some water is probably lost due to evapotranspiration (Rush and Everett, 1964).

Rush and Everett (1964) have estimated the total amount of groundwater recharge to the Kobeh Valley system to be about 17,000 ac-ft/yr (21.9 hm^3/yr). The method originated by Eakin, et al (1951) was used to estimate the groundwater recharge by precipitation in the topographic basin. The distribution of estimated average annual precipitation for Kobeh Valley is listed on Table 2-5.

The entire area of Kobeh Valley which is covered by alluvium has elevations of less than 7,000 feet (2,135 m). Little recharge to the groundwater reservoir occurs in this area because the alluvial materials absorb and hold the small amount of precipitation near the surface and it is eventually discharged by evapotranspiration (Rush and Everett, 1964). However, when applied to the Kobeh Valley area, the method gives an estimated 11,000 ac-ft/yr (13.5

OVERSIZE DRAWING

(Enclosed in Volume II)

FIGURE 2-6

REGIONAL GROUNDWATER FLOW SYSTEMS

hm^3/yr) or about two percent of the total precipitation as groundwater recharge. These results are summarized in Table 2-5.

The methods commonly used to determine estimates of recharge and discharge for hydrographic basins in Nevada are imprecise and have not been updated or refined during the last 20 years. However, during the same period, the understanding of interbasin flow system mechanics has increased substantially. Even so, the Nevada State Engineer considers each hydrographic basin as a separate entity, and as such, does not recognize interbasin transfer of groundwater. As a result, when attempting to interrelate separate hydrographic basins as parts of a more regional flow system, estimates of recharge and discharge between basins seldom balance.

Other sources of groundwater recharge exist for Kobeh Valley by interbasin transfer. It has been estimated that Monitor Valley, entering Kobeh Valley from the southwest, supplies an additional 6,000 ac-ft/yr (7.4 hm^3/yr) of groundwater via interbasin tranfer (Rush and Everett, 1964). Similar transfer would also be expected from Antelope Valley to the southeast. Rush and Everett (1964) state, however, that due to Recent age east-west faulting in the alluvium of northern Antelope Valley, northward flow into Kobeh Valley is impeded. This does not seem reasonable unless such faulting has caused the uplift of impermeable materials to the near surface. This does not appear to be the case in the northern portion of Antelope Valley and it is felt that interbasin tranfer does exist from Antelope Valley to Kobeh Valley. Data are insufficient at present to estimate the quantities of groundwater involved in this process. This view is supported by information obtained from a report by the Nevada State Engineer's Office (1971).

The Western Assemblage rocks which occur above the Eastern Assemblage carbonates are not totally impervious. On a regional basis, downward movement of water through fracture systems results in a relatively small amount of leakance recharge to the carbonate aquifer.

Total annual discharge from Kobeh Valley is estimated to be about 15,000 ac-ft/yr (8.5 hm^3/yr) (Rush and Everett, 1964). The total amount is assumed to be discharged by evapotranspiration. Groundwater in Kobeh Valley has not

Table 2-5 Ground Water Budget for Kobeh Valley 1/

Recharge	Precipitation Zone	Area in Zone	Estimated Annual Precipitation		Estimated Annual Recharge	
Precipitation:	inches (cm)	acres (ha)	feet (m)	acre-feet (ha^3)	Percent of Precipitation	acre-feet (ha^3)
	Less than 12 (30.5)	470,000 (190,350)	0.75 (0.23)	350,000 (430.5)	0	0
	12-15 (30.5-38.1)	65,900 (26,690)	1.12 (0.34)	74,000 (91.0)	7	5,200 (6.4)
	15-20 (38.1-50.8)	22,200 (8,991)	1.46 (0.45)	32,000 (39.4)	15	4,800 (5.9)
	Greater than 20 (50.8)	2,100 (851)	1.75 (0.53)	3,700 (4.6)	25	920 (1.1)
	Subtotal (rounded)	560,000 (226,800)		460,000 (565.8)		11,000 (13.5)
Interbasin Transfer:						6,000 (7.4)
Total:						17,000 (20.9)
Discharge						
Evapotranspiration:						15,000 (18.5)
Interbasin Transfer: (Through Devils Gate alluvium)						negligible
Imbalance: (Recharge-discharge)						2,000 (2.5)

1/ Modified from Rush and Everett (1964).

been extensively developed for use, and therefore discharge due to the pumping of wells is minimal. Discharge from springs in Kobeh Valley totals about 2,500 ac-ft/yr (1,550 gpm) (3.1 hm^3/yr). However, most of this water is used by phreatophytes and is discharged by evapotranspiration. As a result, spring discharge has been accounted for in the total discharge figure given above (Rush and Everett, 1964).

As shown in Table 2-5, there is a positive imbalance of 2,000 ac-ft/yr (2.5 hm^3/yr) in Kobeh Valley. As previously mentioned, only a minimal amount of groundwater can be discharged through the alluvium of Devils Gate. Because permeable Eastern Assemblage carbonate rocks are inferred at depth in these areas, it is reasonable to hypothesize that transfer of groundwater from Kobeh Valley to Diamond Valley occurs in the deep subsurface. Such movement through the Eastern Assemblage aquifer occurs in the area north of Whistler Mountain (Figure 2-6) and probably in the Devils Gate area.

Given the total amount of recharge to, and discharge from Kobeh Valley, an estimate can be made of perennial yield for the system. Perennial yield, as defined by Rush and Everett (1964), is the maximum amount of water that can be withdrawn from a groundwater reservoir and used economically each year for an indefinite period of time. The perennial yield for Kobeh Valley is taken as the average of total recharge and discharge, or 16,000 ac-ft/yr (19.7 hm^3/yr) (Rush and Everett, 1964).

The area of alluvial fill in Kobeh Valley is about 270,000 acres (109,350 ha). Assuming a specific yield value of about 10 percent (Rush and Everett, 1964), 27,000 ac-ft (33.2 hm^3) of groundwater are in storage per foot of the alluvial aquifer.

Diamond Valley. On a regional scale, groundwater moves from south to north in the alluvium of Diamond Valley. Contours of equal water level elevation are illustrated on Figure 2-6. The hydraulic gradient indicates the south to north movement toward the large playa developed at the northern end of the valley, where water levels are at or very near the surface.

Hydraulic gradients are relatively high in southwestern Diamond Valley opposite Devils Gate, but decrease markedly toward the north where the potentiometric surface is nearly flat. This may indicate a component of subsurface flow into Diamond Valley from Kobeh Valley, where water levels are about 100 feet higher than in Diamond Valley.

Harrill and Lamke (1968) have estimated the total amount of groundwater recharge to the Diamond Valley system to be about 30,000 ac-ft/yr (26.9 hm^3/yr). The method used was that described by Eakin and others (1951), which assumes that a percentage of the average annual precipitation will recharge the groundwater reservoir. When applied to the Diamond Valley area, the method gives an estimated 21,000 ac-ft/yr (25.8 hm^3/yr), or about 5 percent of the total precipitation, as groundwater recharge. These results are summarized in Table 2-6.

Interbasin transfer of water through the Sulphur Spring Range via the Eastern Assemblage carbonates at depth is hypothesized as another source of groundwater recharge for Diamond Valley. It is estimated that an estimated 9,000 ac-ft/yr (11.1 hm^3/yr) of groundwater is transferred from Garden Valley to Diamond Valley via the carbonate rocks (Harrill and Lamke, 1968). Evidence substantiating this hypothesis is the presence of several large springs and flowing wells located along the east flank of the Sulphur Spring Range in Diamond Valley. Additional recharge may also be available from Kobeh Valley. As discussed above, Kobeh Valley has a positive recharge-discharge imbalance of 2,000 ac-ft/yr (2.5 hm^3/yr). Based on the present understanding of the geology, and the mechanics of interbasin flow, it is postulated that this amount of groundwater, and possibly more, may be transferred from Kobeh Valley to Diamond Valley through subsurface carbonate rocks.

Diamond Valley appears to be the regional discharge area for water flowing into the basin via interbasin transfer from Newark and Huntington Valleys on the east and Kobeh and Garden Valleys on the west.

Total discharge from Diamond Valley is estimated to be about 30,000 ac-ft/yr (26.9 hm^3/yr) (Harrill and Lamke, 1968). The total amount is assumed to be discharged as evapotranspiration, spring discharge and evaporation from the playa in the northern portion of the valley.

Table 2-6 Ground Water Budget for Diamond Valley 1/

Recharge Precipitation:	Precipitation Zone inches (cm)	Area in Zone acres (ha)	Estimated Annual Precipitation feet (m)	Estimated Annual Precipitation acre-feet (ha^3)	Estimated Annual Recharge Percent of Precipitation	Estimated Annual Recharge acre-feet (ha^3)
		North Diamond Subarea 4/				
	Less than 8 (20.3)	119,300 (48,317)	0.6 (0.18)	71,000 (87.6)	0	0
	8-12 (20.3-30.5)	9,200 (3,726)	0.8 (0.24)	7,400 (9.1)	3	200 (0.3)
	12-15 (30.5-38.1)	47,700 (19,319)	1.1 (0.34)	53,000 (65.2)	7	3,700 (4.6)
	15-20 (38.1-50.8)	14,500 (5,873)	1.5 (0.46)	22,000 (27.1)	15	3,300 (4.1)
	Greater than 20 (50.8)	4,100 (1,661)	1.8 (0.55)	78,200 (8.9)	25	1,800 (2.2)
Subtotal (rounded)		194,800 (78,894)		160,000 (196.8)		9,000 (11.1)
		South Diamond Subarea 4/				
	Less than 8 (20.3)	17,400 (7,047)	0.6 (0.18)	10,000 (12.3)	0	0
	8-12 (20.3-30.5)	197,500 (79,988)	0.8 (0.24)	160,000 (196.8)	3	4,800 (5.9)
	12-15 (30.5-38.1)	46,000 (18,630)	1.1 (0.34)	51,000 (62.7)	7	3,600 (4.4)
	15-20 (38.1-50.8)	12,500 (5,063)	1.5 (0.46)	19,000 (23.4)	15	2,900 (3.6)
	Greater than 20 (50.8)	2,400 (972)	1.8 (0.55)	4,300 (5.3)	25	1,100 (1.4)
Subtotal (rounded)		275,800 (111,699)		240,000 (295.2)		12,000 (14.8)
Total		470,000 (190,350)		400,000 (492.0)		21,000 (25.8)
Interbasin Transfer:						
Garden Valley						9,000 (11.1)
Kobeh Valley 2/						2,000+ (2.5+)
Total:						32,000+ (39.4)
Discharge						
Evapotranspiration:						
Near-surface ground water						15,000 (18.5)
Spring discharge areas						10,000 (12.3)
Northern playa						5,000 (6.2)
Subtotal						30,000 (36.9)
Agricultural Use: 3/ (approximate)						56,000 (68.9)
Interbasin Transfer:						0
Total						86,000 (105.8)
Imbalance: (Recharge-Discharge)						-54,000 (-66.4)

1/ Modified from Harrill and Lamke (1968).
2/ Rush and Everett (1964).
3/ Estimate by HSI.
4/ Division between North and South Diamond Subareas is shown on Figure 2-6.

Another possible source of significant discharge may be a result of the extensively developed agriculture especially in the southern portion of the valley. It is well known that water levels in Diamond Valley have been declining because of the extensive pumping (Harrill and Lamke, 1968). During the last 15 years, water levels have dropped by approximately 30 feet (9.2 m). Harrill and Lamke (1968) have estimated the amount of water in storage per foot of the valley-fill reservoir to be about 28,000 ac-ft (34.4hm^3). During a 15-year period, about 840,000 ac-ft (2,033.2 hm^3) or 56,000 ac-ft/yr (68.9 hm^3/yr), have been withdrawn from the reservoir for agricultural use. These numbers are not precise and a much more detailed study is needed in order to obtain an improve degree of accuracy. For use as a first approximation, the total discharge from Diamond Valley is about 86,000 ac-ft/yr (205.6 hm^3/yr). This can be accepted as a high estimate because a certain volume of water would be salvaged from evapotranspiriation losses by the lowered water table due to pumping.

As shown in Table 2-6, there is a negative imbalance of 54,000 ac-ft/yr (66.4 hm^3/yr) in Diamond Valley. Even though this number is probably high, it illustrates that water levels in Diamond Valley are declining.

For Diamond Valley, the State Engineer's Office (1971) reports a perennial yield of 30,000 ac-ft/yr (26.9 hm^3/yr). This number is assumed to be the average of total recharge and discharge, but it does not include the amount of discharge due to pumping.

Harrill and Lamke (1968) have computed the amount of storage in Diamond Valley based on the distribution of specific yields for various materials described in well logs. The result is that about 28,000 ac-ft (34.4 hm^3) of groundwater are in storage per foot of the alluvial aquifer.

Garden/Pine Valley. On a regional scale, groundwater moves from south to north in the alluvium of Garden Valley. From the contours of equal water level elevation on Figure 2-6, the hydraulic gradient indicates a general south to north movement toward southern Pine Valley where groundwater occurs at an elevation of about 5,600 feet (1,708 m). Water levels are fairly close to the surface over much of Garden and Pine Valleys. Regionally, the groundwater in this hydrographic basin flows north toward the Humboldt River.

The area of investigation for this report covers all of Garden and Denay Valleys, but only a small portion of extreme southern Pine Valley. Since these three valleys are physically interconnected, the groundwater budgets are also interrelated. As such, the Nevada State Engineer (1971) considers all three valleys as one hydrographic basin. The present area of concern covers only a portion of the entire hydrographic basin. Estimation of what portion of the overall groundwater budget applies only to the study area is difficult on the basis of existing data. Therefore, for the purposes of this study, it is reasonable to present the groundwater budget for the entire hydrographic basin.

Eakin (1961) has estimated the total amount of groundwater recharge to the Pine Valley system at about 46,000 ac-ft/yr (56.6 hm^3/yr). The method described by Eakin (1961) was used to estimate the groundwater recharge by precipitation in the topographic basin. The method assumes that a fixed percentage of the average annual precipitation recharges the groundwater reservoir. When applied to the Pine Valley topographic basin, the method gives an estimated 46,000 ac-ft/yr (56.6 hm^3/yr), or about 7 percent of the total precipitation, as groundwater recharge. These results are summarized in Table 2-7.

The total annual recharge to Pine Valley is apparently that which is derived solely from precipitation. At present, there is no evidence to substantiate other sources of groundwater recharge, such as interbasin transfer. However, it is reasonable to assume that some additional recharge from Eastern Assemblage carbonates occurs on a regional scale.

Total discharge from Pine Valley is estimated to be about 33,000 ac-ft/yr (40.6 hm^3/yr) (Eakin, 1961; Harrill and Lamke, 1968). Of this amount 19,000 ac-ft/yr (23.4 hm^3/yr), or about 56 percent of the total discharge, is lost as evapotranspiration. Approximately 17 percent, or about 5,000 ac-ft/yr (6.2 hm^3/yr), is groundwater discharged into Pine Creek. As discussed earlier, it is postulated that the remaining 27 percent, or 9,000 ac-ft/yr (11.1 hm^3/yr), of the total discharge is groundwater transferred from Garden Valley into Diamond Valley through subsurface carbonate rocks.

Table 2-7 Ground Water Budget for Pine Valley 1/

Recharge	Precipitation Zone	Area in Zone	Estimated Annual Precipitation		Estimated Annual Recharge	
Precipitation:	inches (cm)	acres (ha)	feet (m)	acre-feet (ha^3)	Percent of Precipitation	acre-feet (ha^3)
	8-12 (20.3-30.5)	307,000 (124,335)	0.83 (0.25)	254,810 (313.4)	3	7,700 (9.5)
	12-15 (30.5-38.1)	256,000 (103,680)	1.12 (0.45)	286,720 (352.7)	7	20,000 (24.6)
	15-20 (38.1-50.8)	64,000 (25,920)	1.46 (0.59)	93,440 (114.9)	15	14,000 (17.2)
	Greater than 20 (50.8)	11,000 (4,455)	1.75 (0.71)	19,250 (23.7)	25	4,800 (5.9)
Subtotal (rounded)		638,000 (258,390)		654,000 (804.4)		46,000 (56.6)
Interbasin Transfer:						0
Total:						46,000 (56.6)
Discharge						
Evapotranspiration:						19,000 (23.4)
Discharge to Pine Creek:						5,000 (6.2)
Interbasin transfer 2/						9,000 (11.1)
Total:						33,000 (40.6)
Imbalance: (Recharge-Discharge)						13,000 (16.0)

1/ Modified from Eakin (1961).
2/ Harrill and Lamke (1968).

As shown in Table 2-7, there is a positive imbalance of 13,000 ac-ft/yr (16 hm^3/yr) in Pine Valley. The reason for this large divergence is not yet certain. Discharge from springs and wells is eventually lost as evapotranspiration. Groundwater in Pine Valley has not been extensively developed for use by man, so discharge due to domestic and stock consumption is of minor concern (Eakin, 1961). Calculations of subsurface outflow through alluvium at the mouth of Pine Valley show that less than 300 ac-ft/yr (0.4 hm^3/yr) of groundwater is discharged in this manner. With the exception of flow to Diamond Valley from Garden Valley discussed above, no evidence exists to support interbasin transfer of groundwater into other surrounding basins from the Pine Valley hydrographic basin.

Perennial yield is the maximum amount of water which can be withdrawn from the groundwater reservoir for an indefinite period of time without permanent depletion (Eakin, 1961). The amounts of average annual recharge and discharge in the system are the ultimate limits on perennial yield. Because of the large discrepancy between estimates of recharge and discharge, Eakin (1961) assumes a value equal to the discharge of the system. For Pine Valley, then, a preliminary estimate of perennial yield is 33,000 ac-ft/yr (40.6 hm^3/yr).

The area of saturated alluvial fill in Pine Valley is about 200,000 acres (81,000 ha). Assuming a specific yield of about 10 percent (Eakin, 1961), 20,000 ac-ft (24.6 hm^3) of groundwater are in storage per foot of the alluvial aquifer.

2.1.2.3 Phase II Groundwater Study

Hydro-Search, Inc. performed an additional groundwater study (Phase II Hydrology for the Mt. Hope Project) during 1982-1983.

The groundwater reconnaissance portion of the Phase II hydrologic study was an extension of the Phase I study. Wells within a 10-mile radius (16.1 km) of Mt. Hope (Table 2-8) were visited, water levels were measured, a contour map of water levels (Figure 2-7) was prepared and hydrogeologic interpretations of Phase I data were re-examined on the basis of the field reconnaissance results.

Table 2-8 Wells and Springs Within 10-Mile (16.1 Km) Radius of Mt. Hope

Location	Owner, User or Designation	Depth of Well ft (m)	Geologic Source of Water	Elevation at Well 1/ ft (m)	Water Level Below Land Surface Datum ft (m)	Elevation of 2/ Water Level ft (m)	Date of Measurement
Kobeh Valley							
20/49-23ac	BLM (?)	Unknown	Alluvium	6122 (1867.2)	9.5 (2.9)	6112 (1864.2)	8/3/82
20/49-24ba	BLm (?)	Unknown	Alluvium	6140 (1872.7)	6.7 (2.0)	6133 (1870.6)	8/3/82
20/51-2ac	MX Well KB-(0)-1(59)	200 (61.0)	Alluvium	6059 (1848.0)	41.2 (12.6)	6018 (1865.0)	8/3/82
20/51-5ab	Mud Spring	---		6135 (1871.2)	-	6135 (1871.2)	8/3/82
21/50-3cc	MX Well KB-B(0)-2(Y1)	200 (61.0)	Alluvium	6320 (1927.6)	149.1 (45.5)	6171 (1882.2)	8/3/82
21/50-23aa	MX Well KB-0-6(B2)	200 (61.0)	Alluvium	6210 (1894.1)	39.5 (12.0)	6167 (1880.9)	8/3/82
21/51-1cc	BLM (?)	Unknown	Unknown	6280 (1915.4)	203.2 (61.9)	6077 (1853.5)	8/3/82
21/51-24dd	MX Well KB-B(0)-1(W)	200 (61.0)	Alluvium	6160 (1878.8)	84.4 (25.7)	6076 (1853.2)	8/3/82
22/50-31cc	BLM	289 (88.1)	Unknown	6410 (1955.1)	235.4 (71.8)	6175 (1883.4)	8/3/82
22/51-22bd	BLM (?)	Unknown	Unknown	6525 (1990.1)	15.8 (4.8)	6410 (1985.6)	8/3/82
22/51-30bb	Roberta Creek Ranch	350 (106.8)	Alluvium	6480 (1976.4)	334.9 (41.1)	6345 (1935.2)	8/3/82
22/51-31bd	BLM (?)	Unknown	Unknown	6380 (1945.9)	190.3 (58.0)	6190 (1888.0)	8/3/82
Diamond Valley							
22/52-7cd	Gulf hole	1347 (410.8)	Tertiary Volcanics, Western Assemblage	6290 (1918.5)	45.9 (14.0)	6245 (1904.8)	8/3/82
22/52-14ba	View well	Unknown	Alluvium	5862 (1797.9)	49.0 (14.9)	5813 (1773.0)	8/3/82
22/52-16cc	Windmill	Unknown	Alluvium (?), Western Assemblage	6120 (1866.6)	30.1 (9.2)	6090 (1857.5)	8/3/82
22/52-16cc	Mt. Hope Mines	Unknown	Alluvium (?), Western Assemblage	6120 (1866.6)	26.6 (8.1)	6093 (1858.4)	8/3/82
22/52-17dd	Mt. Hope Mines	Unknown	Alluvium (?), Western Assemblage	6120 (1866.6)	30.3 (9.2)	6090 (1857.5)	8/3/82
22/52-26cd	Gravel pit well	Unknown	Unknown	5854 (1785.5)	34.9 (10.6)	5819 (1774.8)	8/3/82
23/52-13bb	Romano Ranch	Unknown	Alluvium	5820 (1775.1)	9.8 (3.0)	5810 (1772.1)	8/3/82
23/52-36cb	Sulphur Spring	---	Alluvium, Eastern Assemblage	5815 (1773.6)	---	5815 (1773.6)	8/3/82
24/52-36cc	Bailey Ranch	Unknown	Alluvium	5800 (1769.0)	10.5 (3.2)	5790 (1766.0)	8/3/82
Garden Valley							
23/51-24bc	Henderson Creek Well	Unknown	Alluvium (?)	6640 (2025.2)	9.7 (3.0)	6630 (2022.2)	8/3/82

OVERSIZE DRAWING

(Enclosed in Volume II)

FIGURE 2-7

WATER LEVEL ELEVATIONS

Results of this work indicated the same general occurrence of aquifers, recharge/discharge relationships and groundwater flow patterns as described in the Phase I report. The relative location of contour lines on Figure 2-6 vs. Figure 2-7 in the Phase I report changed somewhat, but the general pattern remained the same.

2.1.3 Potential Water Sources, Aquifers and Well Fields

The total project water requirements as provided by EXXON would be of a long-term nature, involving a continuous supply of 5,480 gpm.

An area within a 25-mile (40.3 km) radius of Mt. Hope was investigated by Hydro-Search, Inc. (1982) for potential water sources. Three well fields in each of the three hydrographic basins in the vicinity of Mt. Hope (i.e., Kobeh, Diamond, and Garden/Pine Valleys) were identified. The well fields were ranked according to priority for development.

On a regional basis, there are two potential aquifers which could supply the project water requirement. These are: the Quaternary-Tertiary alluvium (QTa) occurring in Kobeh, Diamond and Pine/Garden Valleys, and the Eastern Assemblage limestones and dolomites (EA) that occur at depth below most of the area.

Potential well fields were then located, ranked and evaluated by HSI for the following items:

1. Certainty of supply including the evaluation of the data base at each well location.

2. Water rights acquisition.

3. Well construction and completion which directly reflect well construction costs.

4. Pipeline distances which directly reflect pipeline construction costs.

5. The effects of projected drawdowns from the well fields.

Two well field locations were selected for further analysis: the Kobeh "C" and the Diamond "C". The Kobeh "C" was the highest ranking well field (score 80) and the Diamond "C" was the seventh ranking (score 66). The Diamond "C" well field was chosen due to its close proximity to the project site and because of a previously drilled exploration hole (Gulf Oil) which could be re-entered for hydrologic investigation.

At the present time, the Kobeh "C" well field is located approximately 3.5 miles (5.6 km) north of Kobeh "B" well field on the southwest slope of Mt. Hope about 8.3 miles (13.4 km) south-southwest of the mine site (see Figure 2-6).

The Diamond "C" well field is located on the alluvial flat of Garden Pass Creek at the base of Mt. Hope in the upper reaches of the Diamond Valley hydrographic basin. It is about 2.2 miles (3.5 km) east of the mine site (see Figure 2-6).

Conceptual well field layouts and well field summaries may be found in Appendix 4-B. Projected drawdown for potential well fields may be found in Appendix 4-C. The well field ranking system may be found in Appendix 4-D. (Note: EXXON has proposed development of only a Kobeh Valley well field.)

Exploratory Drilling and Pump Test Program

Hydro-Search, Inc. conducted an exploratory drilling program and pump test program during their Phase II Hydrology study for the Mt. Hope Project (June 1982 - July 1983). During this program, six exploration wells were drilled in Kobeh Valley and one well in the Diamond Valley area, in order to select a suitable site for construction of a test well and perform an aquifer test.

The test well location (KCT #1) was chosen on the basis of the previous exploration hole results. Geologic materials were very similar in all of the exploration holes; however, the thickness of saturated alluvium at KCE #2, in excess of 1,000 feet (305 m), was the major consideration in selecting the

location for KCT #1 (see Figure 2-8). This location is probably far enough south to allow for construction of a well field to the north and/or west without intersecting bedrock at too shallow a depth.

Exploratory drilling in the vicinity of Kobeh "C" shows the alluvial aquifer ranges in thickness from approximately 500 feet (152.5 m) to greater than 1,000 feet (305 m). The alluvial aquifer consists of multi-layered unconsolidated deposits varying from silty clay to coarse sand and gravel. Saturated thickness in the vicinity of well KCT #1 is greater than 1,000 feet (305 m).

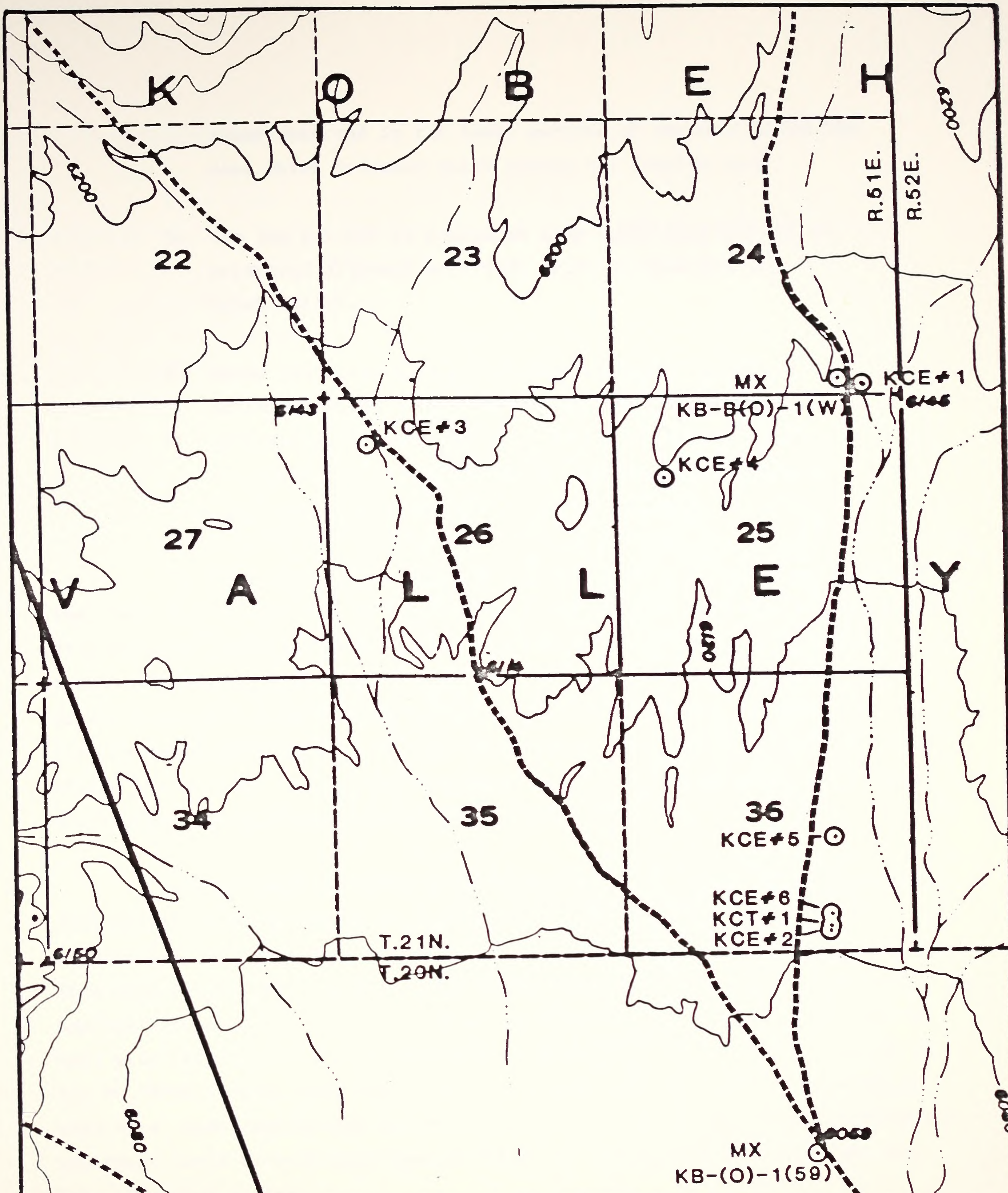
A substantial amount of geological and geophysical evidence collected during the Phase II study indicated, at least indirectly, that an ample water supply for the Mt. Hope Project exists at Kobeh "C". This evidence includes:

1. Drill cutting from all holes drilled at Kobeh "C" indicated that coarse sands and gravels occur throughout the alluvial section penetrated. Some of the gravel zones contained rounded grains over 3/4-inch (1.9 cm) in diameter.

2. Geophysical logs from Kobeh Valley indicated that the alluvial materials are suitably sorted so that they are capable of yielding large quantities of water to a properly constructed well.

3. Geological and geophysical logs (1 and 2, above) were similar to those of prolific groundwater producing stratified alluvial valley fill deposits in other Nevada hydrographic basins.

4. The geophysical log of well KCT #1 shows that the upper 100 feet (30.5 m) of aquifer which produced most of the water during the pumping tests was similar to the lower portion of the log. Those portions of the log corresponding to screened sections in the well should be the most prolific producing zones, and these potentially high-producing



SOURCE: HYDRO-SEARCH, INC., 1983

0 .5 1 Mile

0 .5 1 Kilometer

SCALE
1 : 31,250

MT. HOPE MOLYBDENUM PROJECT

LOCATION OF OBSERVATION WELLS

U.S. Department of the Interior
Bureau of Land Management

FIGURE 2-8

zones occurred in the lower portion of the well below the zone which produced water during the pumping test.

5. The log for KCT #2 indicated over 1,000 feet (305 m) of saturated alluvial materials exist in this area of Kobeh Valley.

6. Notes collected during drilling indicate the loss of drilling fluids to the formation. This required the addition of a large volume of mud and other additives to reduce the loss of fluid and indirectly indicates a high degree of permeability in the aquifer.

The preponderance of evidence indicates that the lower portion of the test well was plugged off and, as a result, the pumping test did not culminate as a reliable indicator of the ability of the Kobeh "C" aquifer to produce water. Although the pumping test program was not successful in providing direct evidence that EXXON's water requirement is available at Kobeh "C" (in the sense of production of high discharge rates), Hydro-Search, Inc. has stated its opinion that an adequate water supply can be developed by a series of properly constructed wells.

The proposed and alternative well fields and their respective water line corridors are shown in Chapter 1.0 of this technical report (refer to Figures 1-2, 1-4 and 1-5). EXXON anticipates that pump tests at the Kobeh Test Site will reveal that the full 5,400 gpm may be obtained from that site alone and has thus proposed EIS evaluation of it as the proposed action. The Kobeh "A" well site (Figure 1-5) was selected as an alternative because it is closer to the Mt. Hope Project site and if a suitable water supply can be developed at this site, construction and operation/maintenance costs of pipeline and related equipment could be much less than at Kobeh "C" (Alternate 3-B) or Kobeh Test Site (Proposed Action).

Information detailing the exploratory drill program and pumping test is presented in Appendix 4-E.

2.2 Groundwater Quality

Water quality analysis and information is necessary to determine existing baseline water quality trends and to establish if present chemical constituents are suitable for mill process water and human consumption. Once the quality of groundwater is assessed, predictions can be better determined as to how the tailings water might influence the groundwater quality beneath and downgradient of the selected tailings pond. Tailings water is expected to contain some metals and have a higher concentration of dissolved minerals than the natural groundwater (see Section 3.5).

Water quality information was obtained from results of chemical analyses on file with the Nevada Department of Health and published USGS survey data.

Eakin (1962) obtained several analyses via written communication from Stuart and Metzger (1961), who were performing an investigation of the mining hydrology in the Eureka region. The selected water samples from Diamond Valley are reviewed in Table 2-9.

Water Quality for Diamond, Kobeh and Garden/Pine Valleys

Representative chemical analyses of groundwaters from the three hydrographic subbasins were compiled by Hydro-Search, Inc. (1982) from the major geologic sources and are presented in Tables 2-10, 2-11 and 2-12. The Hydro-Search report on water quality is given below.

"Because no wells are completed in the Eastern Assemblage carbonates in the area of study, water chemistry for this aquifer is inferred from springs issuing from Eastern Assemblage outcrop areas in various locations. Only partial chemical analyses are available and very few included any of the constituents of the U. S. Primary Interim Drinking Water Standards.

Generally, the groundwater in all three hydrographic basins and both major aquifers appear to be relatively low in total dissolved solids (TDS). Sodium, calcium and magnesium are dominant cations and bicarbonate is the

Table 2-9 Chemical Analyses of Selected Samples of Water from Diamond Valley

Location	Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Specific conductance (Micromhos @ 25°C)	Hardness as $CaCO_3$ Total	Hardness as $CaCO_3$ Noncarbonate	Dissolved solids	Percent sodium	pH
		CONSTITUENTS																		
Fad shaft (19/53-15bd) a/	1-21-53	11	.02	52	26	8.3	1.4	--	238	38	10	0.0	2.6	.06	467	236	42	267	7	7.8
Surface water at Devil's Gate (20/52-26A) a/	4-10-54	21	.47	41	94	1,020	98	35	834	918	800	1.0	.8	1.8	5,370	489	0	3,440	78	8.3
Well (20/53-15cb1) b/	6-6-49	27	.75	37	14	--	--	--	247	16	25	--	--	.2	--	--	--	294	--	8.4
Well (22/54-34ab1) a/	3-10-54	37	.18	78	36	27	5.5	--	356	77	16	.6	5.5	.12	709	342	51	458	14	7.4
Shipley Hot Spr. (24/52-23da) a/	9-18-52	40	.01	57	21	29	5.9	0	279	35	21	.2	.0	.26	540	228	0	346	21	7.2

a/ Analyses by Geological Survey, U.S. Department of the Interior.
b/ Analyses by Twining Laboratories, Fresno, Calif. for Eureka Corporation. Ltd.

Source: Eakin, 1962

Table 2-10 Water Chemistry of Groundwater in Kobeh Valley, Eureka County, Nevada

Well or Spring	EPA-Nevada 1/ Drinking Water Standards	(Hot Spring) 3/ 19/50-5aa	(Warm Spring) 3/ 19/50-8ba	(Lone Mtn. Spring) 3/ 20/50-12dd	(Mud Spring) 3/ 20/51-6ba	(Well or Spring 22/49-27d
Date		7/77	7/77	7/77	7/77	5/19/64
Geologic Source of Water		QTa	QTa-OA?	EA	EA	EA?
Temperature (°C)		--	--	--	--	--
pH	6.5-8.5	7.5	8.6*	8.5	8.4	8.2
Total Dissolved Solids	500s(1000)	354	265	188	334	--
Electrical Conductivity		--	--	--	--	280
Constituent					158	132
HCO_3		76	100	76	12	0
CO_3		40	16	40	14.5	10
Cl	250s(400)	8	11.5	6.5	18	18
SO_4	250s(500)	11	28	11	--	--
F	1.4-2.4p(2)	--	--	--	0.17	--
NO_3	10.0p	<0.02	0.11	0.04	--	--
PO_4		--	--	--	22	23(5)
Na		14	66	14	10	--
K		5.1	7.9	5.1	130	26
Ca		74	11	30	--	6.3
Mg	125s(150)	--	--	--	--	--
SiO_2		--	--	--	--	--
As	0.05p	--	--	--	<0.02	--
Cu	1.0s	--	--	--	0.92*	--
Fe	0.3s(0.6)	--	--	--	0.11*	--
Mn	0.05s(0.01)	<0.02	<0.02	<0.02	0.08	--
Zn	5.0s	0.1	--	0.1		

Notes:

1) Mandatory Nevada and EPA primary standards for public water systems are noted with a "p". Recommended Nevada and EPA Secondary standards for public water systems are noted with an "s". The secondary standard for magnesium is Nevada only. Mandatory Nevada secondary standards for public water systems are shown in parentheses.
2) Dependent on annual average maximum daily air temperature.
3) Analysis by Nevada Division of Health.
4) USGS Field Analysis
5) USGS - "Computed by difference"

Chemical concentrations are in mg/l, pH is in units, and electrical conductivity is in micromhos/cm @ 25°C.

* Exceeds listed standard.
Source: Hydro-Search, Inc., 1982

Table 2-11 Water Chemistry of Groundwater in Diamond Valley, Eureka County, Nevada

Well or Spring	EPA-Nevada[1/] Drinking Water Standards	20/53-21ad[3/]	21/53-3db[3/]	23/52-13ca[3/]	22/54-34ab[3/]	23/52-13ca[3/]
Date		5/9/66	8/17/65	11/19/79	3/10/54	5/5/66
Geologic Source of Water		QTa	QTa	QTa	QTa	QTa
Temperature (°C)		14.4	11.1	--	12.2	16.7
pH	6.5-8.5	7.6	7.8	7.98	7.4	8.3
Total Dissolved Solids	500s(1000)	302	--	538*	458	346
Electrical Conductivity		467	569	--	709	560
Constituent						
HCO_3		220	216	427		
CO_3		0	0	0	356	264
Cl	250s(400)	14	47	27	0	4
SO_4	250s(500)	45	67	48	16	25
F	1.4-2.4p(2)	0.3	--	0.62	77	45
NO_3	10.0p	2.7	--	9.8	0.6	0.4
PO_4		--	--	--	5.5	0.6
Na		17		86	--	--
K			Na+K 69(6)		27	39
Ca		5.1		30	5.5	8.2
Mg		51	16	40	78	41
SiO_2	125s(150)	20	30	33	36	27
As		39	--	--	37	26
Cu	0.05p	--	--	--	--	--
Fe	0.3s(0.6)	0	--	0.82*	0.13*	0.01
Mn	0.05s(0.01)			0.09*		
Zn	5.0s					

Notes:

1) Mandatory Nevada and EPA primary standards for public water systems are noted with a "p". Recommended Nevada and EPA Secondary standards for public water systems are noted with an "s". The secondary standard for magnesium is Nevada only. Mandatory Nevada secondary standards for public water systems are shown in parentheses.
2) Dependent on annual average maximum daily air temperature.
3) USGS detailed analysis.
4) USGS Field Analysis.
5) Analysis by Division of Health.
6) USGS - "Computed by difference"

Chemical concentrations are in mg/l, pH is in units, and electrical conductivity is in micromhos/cm @ 25°C.

* Exceeds listed standard
Source: Hydro-Search, Inc., 1982

Table 2-12 Water Chemistry of Groundwater in Garden/Pine Valleys, Eureka County, Nevada

Well or Spring	EPA-Nevada[1/] Drinking Water Standards	(McCloud Spring)[3/] 23/52-5ac	(Tonkin Spring)[3/] 23 1/2/49-1cc	26/50-34
Date		9/12/79	9/12/79	5/3/70
Geologic Source of Water		OA	WA	QTa
Temperature (°C)		--	--	--
pH	6.5-8.5	7.25	7.95	7.38
Total Dissolved Solids	500s(1000)	253	184	553*
Electrical Conductivity		--	--	--
Constituent				
HCO_3		245	200	573
CO_3		--	35	0
Cl	250s(400)	16.5	6.27	11
SO_4	250s(500)	34	20	35
F	1.4-2.4p(2)	--	--	0.35
NO_3	10.0p	1.1	0.92	0
PO_4		--	--	--
Na		24.5	10	Na+K 64
K		2.1	1.2	
Ca		16.7	16.1	93
Mg	125s(150)	--	--	36
SiO_2		--	--	--
As	0.05p	--	--	0
Fe	0.3s(0.6)	--	--	2.07*
Mn	0.05a(0.01)	<0.01	0.01	--

Notes:

1) Mandatory Nevada and EPA primary standards for public water systems are noted with a "p". Recommended Nevada and EPA Secondary standards for public water systems are noted with an "s". The secondary standard for magnesium is Nevada only. Mandatory Nevada secondary standards for public water systems are shown in parentheses.

2) Dependent on annual average maximum daily air temperature.

3) Analysis by Nevada Division of Health.

Chemical concentrations are in mg/l, pH is in units, and electrical conductivity is in micromhos/cm @ 25°C.

* Exceeds listed standard.
Source: Hydro-Search, Inc., 1982

predominant anion. This appears to be true regardless of the source and location. Elevated levels of iron and manganese are detected in some of the samples. The sparsely scattered incomplete trace metal analyses provide a poor data base for evaluation of these important parameters."

Hydro-Search, Inc. (1982-1983) additionally performed analyses on samples taken from the test well (KCT #1), located in the potential Kobeh "C" well field (Alternate 3-B), in order to compile more accurate baseline water chemistry data. The following text is the water quality report by Hydro-Search based on the KCT #1 test well findings.

"Water samples were collected at approximately 24-hour intervals during the constant discharge test and analyzed for temperature, pH and electrical conductivity. These data are presented below and indicate that the quality of water did not change significantly during the test. Temperature varied between 13 and 14°C, pH between 7.5 and 7.6, and electrical conductivity remained constant at about 700 micromhos/cm at 25°C.

Water Quality Measurements

Sample No.	Date	Time	Temperature °C	pH	Electrical Conductivity (micromhos/cm @ 25°C)
1	5/26/83	1200	13.0	7.5	700
2	5/27/83	1200	13.5	7.5	700
3	5/28/83	1200	13.5	7.6	700
4	5/29/83	1100	13.5	7.6	700
5	5/30/83	1100	14.0	7.6	700

The sample collected at the end of the test was submitted for laboratory analysis of principal ions and trace metals. Results of the laboratory analyses are presented in Table 2-13.

Laboratory analyses show that the water is a calcium-rich mixed cation sulfate type and, according to USGS criteria, falls into the "very hard" classification.

Table 2-13 Water Quality Data

Well	KCT #1	Q = 292 gpm
Date	05/30/83	t = 7140 minutes
Temperature (°c)	14	
pH	7.6	
Total Dissolved Solids (evaporated)	502	
Electrical Conductivity	730	
<u>Constituent</u>		
HCO_3	126	
CO_3	0	
Cl	34	
SO_4	200	
F	0.4	
NO_3 (as NO_3)	4.3	
PO_4 (as P)	1.25	
Na	37	
K	6.5	
Ca	68	
Mg	24	
SiO_2	36	
Al	<0.02	
As	0.007	
Ba	<0.4	
B	0.1	
Cd	<0.01	
Cr	<0.02	
Pb	<0.05	
Hg	<0.0005	
Se	<0.005	
Ag	0.01	
Cu	<0.02	
Fe	0.09	
Mn	0.11	
Zn	0.02	
Hardness as $CaCO_3$	290	

Note: All analyses are in mg/l except pH which is in units and electrical conductivity which is in micromhos/cm @ 25°C.
Source: Hydro-Search, Inc., 1982, 1983.

Except for manganese, the water is below U.S. EPA Primary and Secondary and Nevada Division of Health drinking water standards (Table 2-14). Manganese exceeds the U.S. EPA secondary standard and is at the maximum recommended level of the Nevada Division of Health standard. The total dissolved solids concentration is at the maximum recommended level in the U.S. EPA Secondary Standards but is well below the Nevada Division of Health standard."

2.3 Hydrogeology of the Proposed Mine Site

Hydro-Search, Inc. (1982) performed the hydrogeologic study of the proposed mine site; their report comprises the basis of this entire section.

2.3.1 Geology

Five types of geologic materials of contrasting importance with respect to groundwater hydrology occur in the area of the proposed mine.

Ordovician Vinini Formation (Ov, Western Assemblage). The Vinini Formation exposed in the mine area (Figures 2-9 and 2-10) was deposited in a deep marine environment and is composed of a basal unit of silty argillite, shale and chert and a middle unit of shale with sandstone lenses, argillite and chert. The sandstone lenses are commonly calcareous. The middle unit comprises most of the Vinini Formation at the mine site. The upper Vinini is primarily chert and calcareous argillite and not of widespread occurrence in the mine area.

Devonian Carbonate Rocks (Dd, Eatern Assemblage). The Devonian carbonates are not exposed in the vicinity of the mine but occur at distance in all directions from the site and probably exist at depth below the site. The principal rocks comprising this hydrogeologic group are the Nevada Formation (limestone and dolomite) and Devils Gate Limestone which were deposited in a shallow marine environment. EXXON exploration records indicate that drill hole EMH-3 intersected a skarn at approximately 4,690 feet (1,430.5 m) elevation that may be altered Eastern Assemblage rocks.

Permian Garden Valley Formation (Pg, Overlap Assemblage). These rocks form an abrupt north-south trending ridge east of Mt. Hope. A small outcrop of the

Table 2-14 Drinking Water Standards

U.S. EPA Primary Standards	mg/l	U.S. EPA Secondary Standards	mg/l	Nevada Division of Health Standards	mg/l
Arsenic	0.05*	Chloride	250	Chloride	400
Barium	1.*	Copper	1*		
Cadmium	0.010*	Iron	0.3	Iron	0.60
Chromium	0.05*	Manganese	0.05	Manganese	0.10
Lead	0.05*	pH**	6.5-8.5*		
Mercury	0.002*	Sulfate	250	Sulfate	500
Nitrate (as N)	10.*	TDS	500	TDS	1000
Selenium	0.01*	Zinc	5*		
Silver	0.05*			Magnesium	150
Fluoride	1.4-2.4***				

* Also included in Nevada Division of Health Standards.

** pH units.

*** Depends on average annual maximum daily air temperatures.

Source: U.S. EPA and Nevada Division of Health

OVERSIZE DRAWING

(Enclosed in Volume II)

FIGURE 2-9

GENERALIZED GEOLOGY AND FAULTS
IN THE VICINITY OF THE MINE SITE

OVERSIZE DRAWING

(Enclosed in Volume II)

FIGURE 2-10

GENERALIZED HYDROGEOLOGIC CROSS SECTIONS
IN THE VICINITY OF THE MINE SITE

basal unit of this formation occurs southeast of the proposed mine site (Figure 2-10). This outcrop lies unconformably between the younger Tertiary igneous rocks and the older Vinini Formation at the southeast corner of the site. This lower unit is primarily shallow water limestone altered to skarn due to contact metamorphism by the Mt. Hope intrusive. The skarn is the host rock for the ore mined from the original Mt. Hope Mine.

Tertiary Intrusive Rocks (Ti). These rocks consist primarily of quartz porphyry (Tqp), rhyolite (Tr), granodiorite porphyry (Tgp), and, at depth, granite (Tgr) (Figures 2- 9 and 2-10). Several periods of intrusion are represented. Much of the ore body presently being explored is associated with these rocks.

Quaternary-Tertiary Alluvium (QTa). These poorly consolidated to unconsolidated materials lie directly east of the Mt. Hope mine site and consist of generally poorly sorted materials eroded from the Mt. Hope area. These deposits are relatively thin, probably not exceeding several hundred feet in thickness, due to their position in the upper reaches of the regional drainage system.

Structure

The Ordovician Vinini Formation (Western Assemblage) and Devonian carbonates (Eastern Assemblage) were deposited in a geosynclinal basin. During the Antler orogeny the Western Assemblage was thrust over the Eastern Assemblage along the Roberts Mountains Thrust Fault. The leading edge of the thrust plane occurs in the subsurface a short distance to the east of Mt. Hope, but is covered by the Vinini Formation and surficial alluvium.

The thrust fault is characterized by a breccia zone several tens of feet thick. In some cases slices of the Eastern Assemblage have moved up into the basal unit of the Vinini Formation along subordinate faults. These slices give the appearance of "windows" into the lower plate of the thrust. In reality they probably are entirely isolated by the Vinini Formation from the thrust fault and main body of lower plate Eastern Assemblage beneath the fault.

Based on the projection of regional data, the thrust plane and underlying lower plate Eastern Assemblage rocks are presumed to exist at depth

below the mine site. The carbonates have not been conclusively identified by exploration drilling to an elevation of about 4,000 feet (1,220 m). The carbonates may not be present directly beneath the mine site due to displacement by the igneous intrusive. The carbonates occur beneath the Vinini wall rocks, but their depth is unknown. The vertical and lateral distance of the carbonate rocks from the ultimate pit bottom at 5,000 feet (1,525 m) elevation will be of critical importance in determining the magnitude of mine water inflows.

The Tertiary Period was characterized by multiple intrusive episodes which formed the Mt. Hope igneous complex and ore deposit (Westra, 1980). These episodes caused extensive fracturing, shearing and faulting of the igneous rocks and the country rock. Large scale landslides possibly related to caldera subsidence may have occurred along several arc-shaped normal faults that occur in the vicinity of the site. The most prominent of these features are the Mt. Hope and Ravine Faults (Figures 2-9 and 2-10).

Chemical and thermal activity related to the Tertiary intrusive has affected most of the igneous rocks and surrounding portions of the Vinini Formation altering the latter to hornfels near the margins of intrusive rocks. Beyond this hornfels "rim" the Vinini Formation is presumed to be relatively fresh and extends laterally, relatively uninterrupted for several miles from the mine site.

2.3.2 Groundwater Hydrology

2.3.2.1 Hydraulic Characteristics of Geologic Materials

Hydraulic conductivity (permeability) and storage coefficient are two important parameters used to analyze the flow of water through porous materials. Hydraulic conductivity is a measure of the ease with which water flows through the materials, and storage coefficient is a measure of how much water is released from the materials under a drop in pressure head (e.g., pumping a well).

Much of the rock at the mine site has very low primary hydraulic conductivity and does not store major quantities of water in the bulk, unfractured

form. However, these rocks do store and transmit water through secondary fault and fracture openings.

The various materials in the vicinity of the proposed open pit (i.e., Vinini Formation and igneous rocks) probably exhibit similar hydraulic properties. Actual values are unknown because appropriate measurements have not been made in the mine area. Accordingly, values for the hydraulic parameters have been assigned to these materials based on HSI experience with similar rocks in Nevada and on data from pertinent literature sources (Lohman, 1972; Bureau of Reclamation, 1977; Davis and DeWiest, 1966; Todd, 1959).

Igneous Complex. The igneous rocks at the mine site are of variable type and composition but probably have similar hydraulic characteristics. The values of hydraulic conductivity and storage coefficient are entirely dependent on the number and width of fractures, length and interconnection of these fractures, and on the presence of fault zones with breccia and associated fractures in the wall rocks.

From the logs of exploratory holes, the rhyolite appears to be less fractured than the quartz porphyry but the magnitude of this difference is unknown. In fact, most of the rhyolite occurs above the estimated groundwater level (elevation 6,400 feet (1,952 m). Thus, the rhyolite is of secondary importance with respect to estimation of mine inflows.

Exploration records also indicate that the quartz porphyry which makes up the bulk of rock at depth in the area of the proposed pit is fractured in varying degrees. Degree and occurrence of fracturing are probably controlled by the cooling history of the intrusive and post-solidification movements. The exploration records note the occurrence of numerous fault and fractured zones and of clayey alteration in the secondary openings.

The igneous rocks have been assigned a hydraulic conductivity (K) in the range 0.1 to 1.0 gpd/ft^2 (0.004 to 0.04 m/d). The lower value reflects the essentially homogeneous, small-scale pervasive fracturing of these rocks. The upper value takes into account the occasional pervious fault zones. When taken on a large scale, the heterogenieties of the fault zones average out and the

result is an approximate homogeneous conductive medium of average hydraulic conductivity somewhat higher than if small-scale fracturing alone were taken into account.

Storage coefficient (S) is assigned a value of 0.02 under long-term mine inflow conditions. This value recognizes that a reasonable value for porosity and, thus, yield of water of fractured and faulted igneous rocks, is about two percent. The granite probably shows K- and S-values somewhat less than the overlying quartz porphyry due to the greater depth of burial. For purposes of analysis herein, the values assigned for the quartz porphyry will also be used for the granite.

Vinini Formation. The shale and argillite of the Vinini are very low in primary permeability. The sandstones possibly are slightly pervious, but contain fine-grained materials and calcium carbonate cement which would restrict permeability. The sandstone, chert and limestone beds, although restricted in thickness and extent, could contain secondary fracture openings. In addition, pervious fault zones may occur in this unit. Taking all factors into account, the Vinini has been assigned a hydraulic conductivity value in the range of 0.05 to 0.5 gpd/ft^2 (0.002 to 0.02 m/d) and a long-term storage coefficient value of 0.01. These values are applicable to the Vinini away from the immediate mine area.

The hornfels zone of the Vinini around the igneous complex probably is more fractured than the Vinini away from the mine, and K- and S-values probably are similar to those of the igneous complex.

Mt. Hope and Ravine Faults and Similar Major Zones. The Mt. Hope Fault and possible other similar major structural features are anticipated to have relatively high hydraulic conductivity based on lost circulation data in the drilling records. Storage is probably more than for the igneous and Vinini wall rocks. A hydraulic conductivity value of 100 gpd/ft^2 (4.0 m/d) and a long-term storage coefficient of 0.05 have been assigned to this and similar major faults.

The values discussed above may be slightly high but are within a reasonable range for the materials and lead to a slightly conservative bias in

the estimate analysis of mine water inflow presented as impact discussion in Section 3.4.

2.3.2.2 Groundwater Flow System

Based on estimated groundwater levels in Diamond and Kobeh Valleys and on a well in the Vinini Formation several miles east of the proposed pit, the groundwater level in the pit area is estimated to be about 6,400 feet (1,952 m) elevation. This water level slopes downward, from a high point under Mt. Hope, toward Diamond and Kobeh Valleys. Thus, flow from the Mt. Hope area has an outward component toward these valleys. Perched water may exist above 6,400 feet (1,952 m) elevation in the pit area and could be within 50 to 100 feet (15.3 - 30.5 m) of the surface. However, any such perched water would not be connected to a major source of replenishment, and would receive recharge only from precipitation infiltrating through fractures in the rocks.

If Eastern Assemblage carbonates exist at depth beneath the mine site, water in these rocks would be under substantial artesian pressure because of the confining effects of the overlying, low permeability Western Assemblage and igneous rocks. The hydraulic potential (positive pressure) at the top of the Eastern Assemblage is estimated as 6,000 feet (1,830 m) elevation. Considering the high hydraulic conductivity and regional replenishment potential of these rocks, any hydraulic connection with the proposed pit (e.g., along a major fracture or fault zone in the Vinini Formation or igneous rocks) could result in substantial inflows in the latter stages of pit development. The final pit floor is projected for elevation 5,000 feet (1,525 m), giving a difference of hydraulic potential of 1,000 feet (305 m) of water between the carbonates and the pit floor. At present, no direct evidence exists to substantiate either the presence of these carbonate rocks at depth below the mine area or of any type of direct hydraulic connection to the proposed pit bottom.

2.3.3 Hydrology of Tailings Pond Sites

The hydrological characteristics of the three alternative tailings pond sites (refer to Chapter 1.0, Figures 1-2 and 1-4) were studied for hydro-

logical suitability. These same hydrological characteristics were also studied in relation to the influence each pond may have due to seepage, surface water interception, drainage modification and the groundwater flow and quality beneath and downgradient of each pond.

The Garden Pass site (Alternate 4-A - the proposed action) would be approximately two miles east of the mill site with the impoundment dam located about 2,000 feet upstream of the narrow gap in the Sulphur Springs Range. The site would be at the mouth of a 12,352 acre drainage. Ultimately, tailings in the pond at Site 4-A would cover approximately 3,460 acres.

The Diamond Valley site (Alternate 4-B) would be approximately six miles east of the mill, would have an ultimate size of 5,650 acres and would be surrounded by a dike. The site would be on the very gently sloping valley bottom. Drainage area affected by this site would be limited to the 5,650 acres enclosed by the pond dikes.

The Upper Kobeh Valley site (Alternate 4-C) would be located approximately 3.6 miles south of the mill, would have a drainage area of 3,930 acres and an ultimate tailings pond size of 2,173 acres. The site would be located on an alluvial fan that slopes gently southward from Mt. Hope.

Detailed groundwater studies have not been conducted at any of the alternative dam and tailings pond sites. Geologic studies involving core analysis and stress response have been conducted at Alternates 4-A and 4-C (see Technical Report No.2)

Geological data for Alternate 4-A (Garden Pass) indicates the pond would be underlain by several hundred feet of unconsolidated alluvium composed of lenses and mixtures of sand, gravel, silt and clay. Beneath the alluvium at an undetermined depth is bedrock of the Western Assemblage comprised of shale, chert, quartzite and minor limestone units. The Vinini Formation (Western Assemblage) underlies the upstream 60 percent of the proposed tailings pond (Hydro-Search, Inc., 1982). For the remainder of the pond area (downstream 40 percent) alluvium is probably underlain by Overlap Assemblage bedrock, primarily Garden Valley Formation, consisting of siliceous limestone, conglomerate and

sandstone (Hydro-Search, Inc., 1982). This geological interpretation also is consistent with field reconnaissance information from Wahler Associates (1983). The prominent hogback ridge at the proposed tailings pond abutments is comprised of a steeply dipping, siliceous pebble conglomerate of the Garden Valley Formation or, for the nearby alternate dam alignment, quartzites of the Vinini Formation and shales and sandstones of the Garden Valley Formation.

Tailings pond Alternate 4-B (Diamond Valley) would be underlain by unconsolidated silty alluvium that is estimated to be several hundred feet thick and the shallow alluvial layers are probably collapsable (Wahler Assoc., 1983). Collapsable alluvium consolidates or decreases in volume when wetted.

Alternate 4-C, sited on a broad alluvial fan on the northeastern edge of Kobeh Valley, is presently drained by several ephemeral drainage courses emanating from the foothills south of Mt. Hope. Strata beneath the site consist of silty alluvium deposited by ephemeral streams underlain by coarser and older alluvium consisting of several hundred feet of lenses and mixtures of gravel, cobbles, sand and silt (Wahler Assoc., 1983). Beneath the alluvium, bedrock of the Eastern Assemblage (Nevada Formation) and Western Assemblage (Vinini Formation) is present (Wahler and Assoc., 1983). Nevada Formation exposed at the site is dominately a limestone while the Vinini Formation is primarily a quartzite. The west end of the impoundment dam would abut a ridge of faulted limestone and quartzite and the east dam abutment would be in quartzite.

2.3.4 Surface Water Hydrology

The Mt. Hope project is located near the intersection of three major drainage basins: 1) Diamond Valley to the east, 2) Kobeh Valley to the south and west, and 3) Garden Valley to the north and west (see Figure 2-11). For the Phase I hydrology study conducted by Hydro-Search, Inc. (1982), four minor drainage basins were evaluated: 1) Garden Pass Creek Watershed, 2) Stinking Spring drainage area in Diamond Valley, 3) Northwest (NE) and North Central (NC) Kobeh Valley drainage area in Kobeh Valley, and 4) Henderson Creek Watershed in Garden Valley (see Figure 2-11).

OVERSIZE DRAWING

(Enclosed in Volume II)

FIGURE 2-11

REGIONAL SURFACE WATER DRAINAGE

Average annual precipitation in Diamond Valley is about 8 inches (20 cm) while annual precipitation in the nearby mountains averages about 16 to 20 inches (41 to 51 cm). The precipitation gage nearest Mt. Hope project site is located on the floor of Diamond Valley and has 13 years of record. Use of the Diamond Valley data, however, could incorrectly estimate annual and event-related precipitation for the Mt. Hope project site.

No perennial streams exist in the four drainage basins under investigation with the exception of a portion of a tributary to Henderson Creek which originates from springs. This stream is located 2.8 miles (4.5 km) northwest of Mt. Hope in Garden Valley. Garden Pass Creek and Henderson Creek are major ephemeral streams. The northeast and northcentral portions of Kobeh Valley and the eastern flank of Sulphur Spring Range are drained by numerous small ephemeral streams. Streamflows in Diamond Valley and Kobeh Valley terminate in the playas on the valley floors.

Three minor springs (<1.0-2.0 gpm) are known to exist in the Mt. Hope area: Mt. Hope Spring, Garden Spring and McBrides Spring. All of these are located within 2.0 miles north/northeast of the Mt. Hope summit. An unidentified seep area also exists in the proposed tailings area (Alternate 4-A) and is characterized by a wetted muddy area. Larger and better known springs in Eureka County, Nevada are shown in Table 2-15.

The only streamflow data for the area are annual maximum discharge at crest-stage partial-record stations located on Garden Pass Creek (Gage 1) and a tributary of Garden Pass Creek (Gage 2) (USGS) (Figure 2-11). Annual maximum discharges for these stations are listed in Table 2-16.

The field reconnaissance for surface-water hydrology was performed by Hydro-Search, Inc. (HSI) personnel from July 21 to July 24, 1982. Included in the field reconnaissance were:

1. Location and inspection of principal stream channels to determine stream type, estimation of annual flow regimes and observation of high-water marks and other evidence of historical flooding.

Table 2-15 Larger and Better-Known Springs of Eureka County, Nevada

Map No.	Name	Location	Discharge (gallons per minute)	Date Measured	Reference	Remarks
22	Fish Creek Springs (Sara Ranch Springs)	Sec. 8, T16N, R53E, 17 miles south of Eureka	4,000	Prior to 1935	WSP 679B, p. 162	Six springs
23	Hot Springs	Sec. 12, T28N, R52E, 27 miles south of Carlin	2,000 est.	1960	Rec. 2, p. 26	
24	Shipley Hot Springs (Sadler Springs)	NE 1/4 SE 1/4 Sec. 23, T24N, R52E, 31 miles north of Eureka	5,000	1960	USGS files	Thermal
25	Thompson Ranch Springs (Jacobson Ranch Sprgs)	SW 1/4 Sec. 3, T23N, R54E, 28 miles north of Eureka.	900 est.	Prior to 1935	WSP 679B, p. 162	
52	Klobe Spring	Sec. 28, T18N, R50E	450 est.	4-15-64	USGS files	Two springs. Thermal.

More detailed information on these springs is available in the reference listed.

The abbreviations listed under references refer to:
- WRB - Nevada Water Resources Bulletin.
- Rec. - Nevada reconnaissance series report.
- WSP - U.S. Geological Survey Water-Supply Paper.

The word "Thermal" designates springs whose temperature is 90° or greater.

Source: State of Nevada, Division of Water Resources, 1971.

Table 2-16 Annual Maximum Discharges in Garden Pass Creek Watershed

Station Name, Number	Garden Pass Creek (1024 6010) (Gage 1)	Garden Pass Creek Tributary (1024 6000) (Gage 2)
Location	Lat. 39°46'45" Long. 116°09'52"	Lat. 39°40'00" Long. 116°09'52"
Drainage Area	19.2 mi^2	2.12 mi^2
<u>Water Year</u>	<u>Peak Discharge, cfs</u>	
1962		0
1963		0
1964		1.0
1965	650	0.3
1966	100	0.1
1967	80	46.0
1968	15	47.0
1969	20	0.5
1970	0.7	1.0
1971	108	0.1
1972	150	18.0
1973	4	0
1974	4	0.5
1975	165	0.6
1976	1	0
1977	20	0.2
1978	1	0.3
1979	missing	1.5
1980	7	0.5
1981	0.5	0
1982	no data collected	0.2

Notes: Peak discharge estimated from annual maximum gage height.

SOURCE: USGS

2. Location and inspection of USGS crest-stage gages and characterization of the associated stream channel control sections.

3. Observation of soils and vegetative cover and density to verify site-specific watershed parameters to be used for SCS runoff estimates.

4. Measurement of channel cross sections and longitudinal gradients of the principal drainage courses at significant locations for input to storm runoff routing calculations.

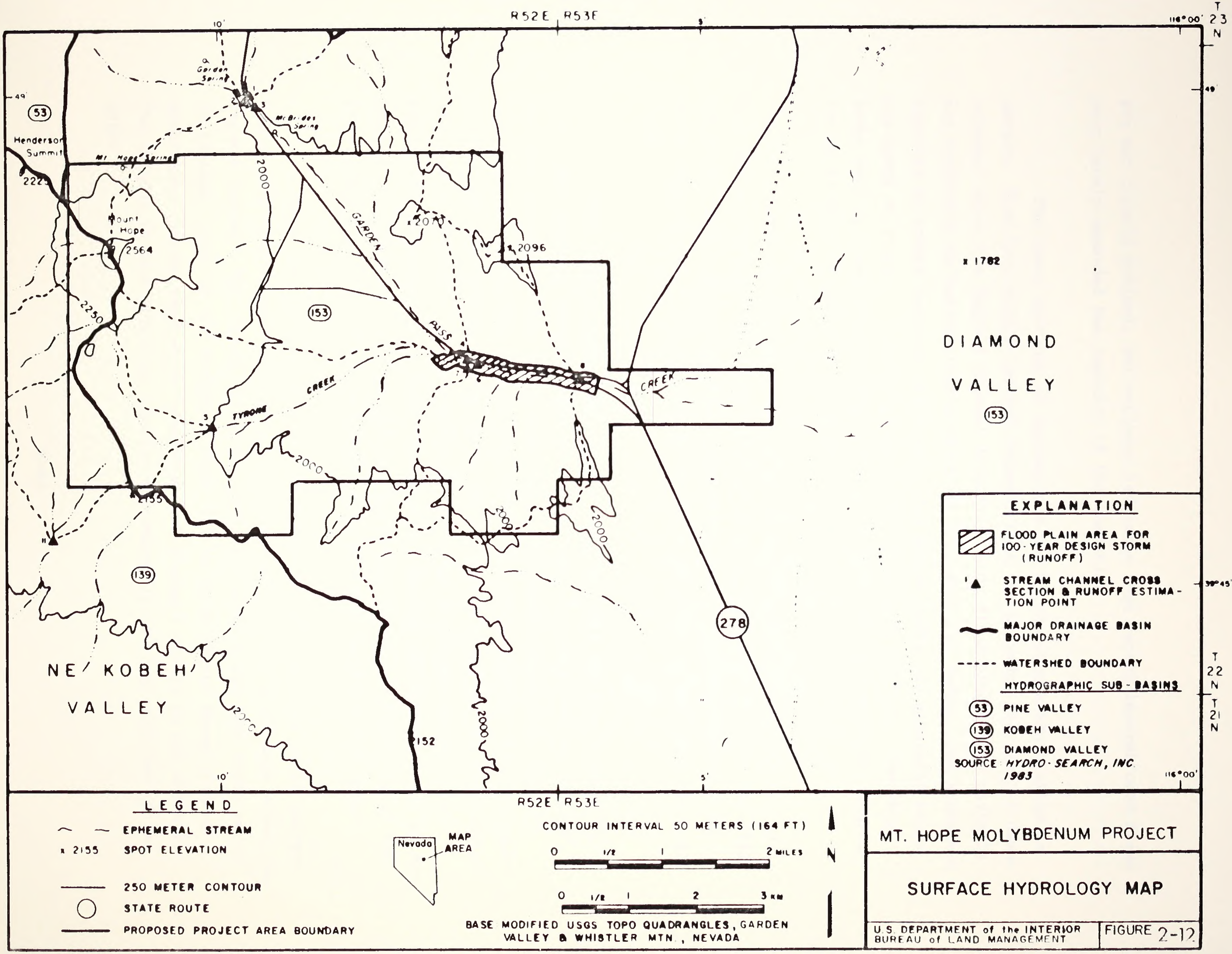
Items 1 and 3 involved a general reconnaissance of the area of investigation, in particular those areas adjacent to the principal stream courses. Soils and vegetation were inspected, visually classified and/or sampled throughout the area and compared with known information. General characteristics of stream courses and topographic features were noted.

Items 2 and 4 involved a detailed analysis of significant reaches of the principal stream channels. Channels at the outlet of major watersheds and/or sub-watersheds and at the USGS crest stage gages were evaluated in detail. Channel cross sections were measured. Samples of streambed and bank materials were collected and visually classified to verify data from soil surveys (Archer, 1980 and Soil and Land Use Technology, Inc., 1980). Significant hydraulic features of the stream reach and channel cross sections were noted.

The following discussion reviews precipitation, runoff and physical characteristics of watersheds near the Mt. Hope project site as compiled by Hydro-Search, Inc. (1982-1983) during the Phase I and Phase II hydrology studies.

The principal stream channels in the area of investigation are Garden Pass and Tyrone Creeks (Garden Pass Creek watershed) and unnamed streams draining Northeast Kobeh Valley watersheds (Figure 2-11 and 2-12).

The upper portions of Garden Pass and Tyrone Creeks and the Kobeh Valley streams are similar in nature. They have slightly incised stream channels with no significant associated flood plain. Channels are moderately to heavily vegetated, showing little streambed erosion or deposition. High water marks



MT. HOPE MOLYBDENUM PROJECT

SURFACE HYDROLOGY MAP

U.S. DEPARTMENT of the INTERIOR
BUREAU of LAND MANAGEMENT

FIGURE 2-12

are not clearly defined, but evidence indicates that recent intermittent flows very rarely exceeded the capacity of the channels.

The lower portions of Garden Pass and Tyrone Creeks are similar in nature. They have deeply incised channels that become wider and flatter downstream. Above the incised channel is a flat, wide flood plain. The channels are moderately to heavily vegetated on the streambed and banks. The streambed consists of eroded upstream materials. The stream banks are generally steep and prone to erosion. High water marks are not clearly defined. Unstable banks tend to undercut and slough into the channel during high flows, leaving little evidence of historic flooding.

Annual maximum discharge at Garden Pass Creek (Gate 1) was 0.5 cubic feet per second (cfs) for 1981. No data were collected at this site for 1982 (Squires, 1983). Annual maximum discharge on the tributary of Garden Pass Creek (Gage 2) was 0 cfs and 0.2 cfs for 1981 and 1982, respectively (Squires, 1983).

Gage 1 is located about 40 feet upstream of a concrete culvert (11.5 feet wide) crossing beneath State Route 278, near the center of the channel. The main channel is five to six feet wide. The entire channel is about 45 feet wide and is incised four to five feet below ground level. The streambed consists of fine-grained eroded materials covered by sagebrush and rabbitbrush (20 percent density). Significant bank sloughing is present on the outer radius of the channel just above the culvert. Erosion and deposition of materials in the stream channel control section causes transient conditions at the crest-stage gage and, therefore, high potential error in streamflow data.

Gage 2 is located about 10 feet upstream of a circular metal culvert (three feet wide) crossing beneath State Route 278, on the north bank above the channel bottom. The channel is narrow with only about a one foot width which is incised. Most of the streambed shows little or no recent deposition of materials. Sparse vegetation (sagebrush and grasses) occurs in the channel. The channel is much wider and flatter approximately 100 feet upstream of the gage.

The surface water drainage characteristics described above have been used to estimate the magnitude of runoff events having a recurrence probability of 0.01 (i.e., 100-year storm). To improve design storm runoff and flood routing estimates originally calculated during Phase I study efforts, eleven stream channel cross sections were surveyed at the outlets of major watersheds and sub-watersheds (Figure 2-13). Dimensions of the cross sections are shown on Figures F-1 through F-6 in Appendix 4-F. Analyses of design storm runoff and flood routing are presented in Section 3.3.

OVERSIZE DRAWING

(Enclosed in Volume II)

FIGURE 2-13

SURFACE WATER DRAINAGE FEATURES AND 100-YEAR FLOOD PLAIN

CHAPTER 3.0

IMPACT ANALYSES

3.1 Introduction

The analysis of potential hydrologic resources impacts was conducted with an emphasis on the following major criterion of effects:

1) Flood plain development and/or alteration
2) Mine pit inflow relative to Kobeh Valley demand
3) Tailings pond effluent quality and seepage character
4) Groundwater withdrawal
5) Erosion (Technical Report No. 5, Soils)

While other potential impacts may be identified, some of which are included in this Technical Report, the above listed points of emphasis represent the items of significant concern brought forth during EIS public scoping meetings and various agency communications.

Pertinent assumptions and certain guildelines to analysis of impact are listed in Section 3.2. The multiple analysis of potential hydrologic resources impacts involved professionals from several consulting firms, as well as the interface with EXXON specialists in mineral processing, tailings dam design and materials handling, and mining hydrology. While WRC responsibilities included impact analysis as well as Technical Report preparation, the study results of specialists in certain topical analyses have been wholly and/or partly utilized to provide not only a comprehensive overview of baseline hydrologic conditions (Chapter 2.0) but also to assure appropriately detailed analyses of impact in each topical area. The following specifies involvement in addition to that of WRC and BLM on a topical basis.

1) Flood plain determination: Hydro-Search, Inc.
2) Mine pit inflow: Call & Nicolas, Inc.
3A) Tailings pond effluent quality: various laboratories; EXXON Minerals Company

3B) Tailings seepage: Wahler Associates; Hydro-Search, Inc., EXXON Minerals Company

4) Groundwater withdrawal: Hydro-Search, Inc.

Sections 3.3 through 3.6 detail the anticipated hydrologic impacts determined by analysis of implementing the proposed action and/or alternatives. Implementation of the no action alternative would negate the occurrence of impacts herein associated with the proposed action.

3.2 Assumption and Analysis Guidelines

The determination of environmental impacts upon the hydrologic resources base required that certain assumptions be made which would affect conclusions regarding significance of impact and nature of impact (beneficial/detrimental). The general assumptions used in the analyses are presented below.

1. It was assumed that the proposed action and alternatives, particularly the use and management of process water, described briefly in Chapter 1.0 of this Technical Report and in detail in Chapter 2.0 of the EIS and Technical Report No. 1 would be implemented as described. Mitigation measures described in the EIS would be in place at time designated and as described. Assumptions 2 through 11 below highlight particularly important aspects of the proposed action and alternatives described, as related to hydrologic resources.

2. The proposed action would result in the disturbance of the following acreages of land:

	Temporary
Mine Pit	700 acres
Non-Mineralized Material Storage Areas (2)	2,400 acres
Tailings Pond 4-A	3,460 acres
Evaporation Pond	164 acres
Plant Site and Auxiliaries	100 acres
Site Access Road	30 acres
Powerline 2-A (3.5 acres/mile)	77 acres
Water Line	132 acres
State Route Relocation	67 acres

Approximatley 200 acres would be impacted by the proposed development of an employee subdivision. The impacts associated with the subdivision development relative to hydrologic resource effects were not evaluated because of the uncertainty of eventual subdivision siting location.

The alternatives (excepting the no action alternative) would, upon implementation, result in the alternate disturbance of the following acreages of land.

Power Line 2-B	73.5 acres
Power Line 2-C	80.5 acres
Power Line 3-B	108 acres
Power Line 3-C	96 acres
Power Line 3-C	96 acres
Tailings Pond 4-B	5,650 acres
Tailings Pond 4-C	2,173 acres

3. Of the areas undergoing initial project activity disturbance, contemporaneous reclamation would occur only along rights-of-way corridors and within the areas of the process plant site between corridors. Remaining areas would not be reclaimed until cessation of ore removal operations. Upon cessation of mining, the mine pit and non-mineralized material storage areas would not be reclaimed, all other areas would be reclaimed.

Of the areas undergoing contemporaneous reclamation, the following operational acreage disturbances would occur through mine life (or permanent if roads, power line and water line are left intact for other use).

Proposed Action	Initial Acres	Contemporaneous Acres
Power Line 2-A	77	40
Power Line 3-A	132	42
Alternatives		
Power Line 2-B	73.5	38
Power Line 2-C	80.5	41
Water Line 3-B	108	34
Water Line 3-C	96	25

4. Reclamation after construction (rights-of-way corridors and inter-plant acres) would consist of stockpiled topsoil redistribution, regrading and revegetation of a ground cover as soon as possible after the construction activity was completed. Construction periods would be 11 weeks for power line; 12 to 16.5 weeks for water line; and up to two years for process plant components. The erosion control mitigation measures described in Technical Report No.1 and the EIS have been assumed to effectively negate significant hydrologic impacts. This assumption was deemed appropriate in light of the lack of surface water body presence in the areas affected.

5. Surface runoff from the site, including that from non-mineralized material and ore storage areas, would be collected and routed to the tailings pond. As appropriate, stone rip rap and diversion ditches would be constructed to control runoff and erosion. If necessary, small catchment basins would be included in the soil erosion control plan. A larger basin would be constructed at the foot of the tailings dam to intercept and collect runoff from the dam face. The collected water would be intermittently pumped to the tailings pond.

   Surface water runoff from undisturbed areas would be diverted from the tailings pond area and allowed to discharge beyond the tailings pond dam. Erosion control features would be implemented to assure flood control and degradation of surface water quality.

6. Routine site erosion inspections would be conducted throughout the years of operation. Detected erosion problems would be corrected in a timely manner as a standard operating procedure. In this respect, particular attention would be given to the tailings dam.

7. Final reclamation of the tailings pond would primarily entail, in part the following, as determined by regulations existing to date.

   After the tailings pond surface has dried out, approximately two feet of rock from the non-mineralized material storage areas would be placed over the tailings. As much as possible, this rock layer would then be covered with the overburden/topsoil stockpiled during construction. The cover

would then be seeded with the groundcover specified above and pinyon and/or juniper trees would be planted. This cover would be contoured so as to minimize seepage of precipitation into the tailings.

The slope of the final cover surface would be graded appropriately and the downstream face of the tailings pond dam would be recontoured to the extent necessary to maintain stability and control erosion during the tailings basin dry-out period. Additionally, the pond reclamation effort would assure that other area surface water runoff would be directed away from the reclaimed pond so as not to allow flooding or infringement into the tailings pond material.

8. It was assumed that a life-of-mine groundwater monitoring program would take place in two parts: 1) monitoring of groundwater availability in Kobeh Valley as per the State Engineer's conditions to granting EXXON water rights equalling 5,400 gallons per minute in Kobeh Valley and 2) monitoring of groundwater quality in the project vicinity and Kobeh Valley.

   It was further assumed that in accordance with EXXON's water rights permits three monitoring wells will be drilled at:

   1. NE 1/4 Section 25, T. 22 N., R. 50 E.
   2. SE 1/4 Section 35, T. 22 N., R. 50 E.
   3. SE 1/4 Section 27, T. 22 N., R. 50 E.

   These wells would be drilled and cased to an approximate minimum depth of 400 feet and approximately the bottom 100 feet of casing will be perforated. Groundwater depth in these wells would be monitored and reported to the State Division of Water Resources as follows:

Time Period	Monitoring Frequency	Reporting Frequency
Mine Construction (1st year)	monthly	quarterly
Remainder Mine Construction	quarterly	quarterly
Mine Production (1st 2 years)	quarterly	quarterly
Remainder Mine Production	semi-annually	semi-annually

The groundwater quality monitoring program agreed to by EXXON and the Nevada State Department of Environmental Protection in conjunction with a required Zero Discharge/Groundwater Infiltration permit (see Item 10 below) would include monthly chemical analysis of samples from three wells. The wells would be located at Mt. Hope spring, the Kobeh Valley water supply site and in the Garden Pass drainage subbasin.

Finally, monitoring wells would be installed at the foot of the tailings dam to regularly check for potential changes in groundwater quality related to seepage from the tailings pond. The frequency of monitoring and parameters tested for would be mutually agreed to by EXXON and the Nevada Division of Environmental Protection. If necessary, seepage would be intercepted by a series of wells and pumped back to the tailings basin.

9. As discussed in detail in Technical Report No.1, EXXON would be required to achieve a no discharge standard at the tailings pond for its process design in two point source categories (ore mining and dressing, molybdenum dressing.) To do so, EXXON would employ measures recommended by the EPA, and considered by that Agency to be best available demonstrated technology (BADT). Among these measures are recycling process water from the concentrator, employing the tailings pond and lined pond as evaporation/settling basins, and lime precipitating wastewater flow from the hydrometallurgical plant.

10. Seepage from the tailings basin would be regulated through issuance of a Zero Discharge or Subsurface Injection/Infiltration permit by the State of Nevada Department of Environmental Protection under the authority of NRS 445.131 through NRS 445.354. Which of these permits is issued would depend upon the nature of the seepage and the design of the tailings pond.

EPA toxicity tests show that the tailings would not be classified as hazardous (see Technical Report No.5). Although no long-term significantly adverse effects from seepage from the tailings basin to groundwataer are expected, it has been assumed that a clay or synthetic liner would be installed if permit analyses and/or approval requirements necessitated such.

It has been assumed seepage would be minimized by EXXON's commitment to segregate the tailings such that the fine fraction tends to form a self-seal. Upon start-up, the tailings would be cycloned and the coarse-sized fraction (sands) would be deposited at a point on the south side of the basin. The fine-sized fraction (clays) would be piped to the inside of the starter dam and deposited along the bottom and sides of the basin to a minimum thickness of approximately 10 ft (3 m). This fine-grained material would tend to seal the bottom and sides of the tailings pond, substantially reducing the rate of seepage.

11. Sanitary wastewaters would be discharged only under permit conditions and as set forth in Technical Report No.1.

Several additional specific assumptions are discussed in each of the following Sections, as well as in each appendix.

3.3 Flood Plain Analysis

Within the area of investigation for Phase I HSI studies, nine watersheds or sub-watersheds were chosen, as per instructions of EXXON, for design storm runoff analysis under Phase II. Six of these drainages lie in Diamond Valley: a) Upper Garden Pass Creek (North), b) Upper Garden Pass Creek (West), c) Central Garden Pass Creek, d) Upper Tyrone Creek, e) Lower Tyrone Creek, and f) Lower Garden Pass Creek. Three of the watersheds are in Kobeh Valley: a) Upper Northeast Kobeh Valley #1, b) Lower Northeast Kobeh Valley #1, and c) Upper Northeast Kobeh Valley #2 (see Figure 2-13).

HYMO, a rainfall-runoff computer model developed by the Agricultural Research Service, USDA (Williams and Hann, 1972) which performs calculations based on the SCS method for estimating rainfall-runoff from small ungaged watersheds and on the Variable Travel Time (VTT) method (Williams, 1975) for routing storm runoff, was used to estimate runoff resulting from the design precipitation event. The 100-year, 6-hour and 24-hour storms were used as the design precipitation events. At Mt. Hope, the design point precipitation was estimated at 1.9 inches and 2.8 inches, respectively (Miller, et al, 1973).

The SCS method uses a simple mathematical model based on generally accepted rainfall-runoff relationships to estimate the magnitude and temporal distribution of runoff from small watersheds. Various watershed characteristics are determined and quantified as parameters for the rainfall-runoff model (i.e., watershed dimensions, soils and vegetation and antecedent moisture conditions).

HYMO performs the flood-routing calculations, based on the VTT method, using channel geometries and lengths of stream reaches. An explanation of procedures for estimating routed 100-year storm runoff is given in Appendix 4-F. Routed storm runoffs estimated by HYMO are summarized in Table 3-1 and shown on Figure 2-13.

Potential for flooding exists only in the lower reaches of Garden Pass Creek and Tyrone Creek (Figure 2-13) based on the estimates of storm runoff and general characteristics of the Mt. Hope area.

Overbank flow is probable from Cross Section 8-Lower Garden Pass Creek upstream to Cross Section 7-Central Garden Pass Creek. The topography is relatively flat and Garden Pass Creek has a deeply incised meandering channel.

Overbank flow is probable from Cross Section 6-Lower Tyrone upstream part of the way toward Cross Section 5-Upper Tyrone Creek, above the confluence of Tyrone and Garden Pass Creeks. The upstream limit of potential flooding cannot be determined more precisely than this.

Overbank flow is probable from Cross Section 4-Upper Central Garden Pass Creek upstream toward State Route 278 or above. An abandoned railroad grade lies roughly parallel to State Route 278 between where Garden Pass Creek crosses beneath the road and the downstream confluence with Tyrone Creek (Figure 2-13). The railroad grade, which is elevated six to eight feet above ground level in this area, acts as a levee, channelling the stream between the road and railroad grade until the railroad grade is breached by the stream just above the confluence. The limit of potential flooding cannot be determined precisely, but may be as far upstream as State Route 278 or above.

Table 3-1 Estimated Storm Runoff Routed through Stream Channel Cross Sections

Stream Channel Cross Section	Drainage Area ac. (ha)	6-Hour Runoff Event: Peak Discharge cfs (m^3/s)	6-Hour: Time to Peak hours	6-Hour: Total Runoff in.(cm)	6-Hour: Total Runoff AF(hm^3)	24-Hour Runoff Event: Peak Discharge cfs (m^3/s)	24-Hour: Time to Peak hours	24-Hour: Total Runoff in.(cm)	24-Hour: Total Runoff AF(hm^3)
1-Upper Garden Pass Creek (North)	503 (203.7)	57 (1.61)	3.50	0.43 (1.09)	18.0 (0.022)	92 (2.61)	9.75	0.98 (2.49)	41.1 (0.051)
2-Upper Garden Pass Creek (West)	1374 (556.5)	269 (7.62)	3.00	0.68 (1.73)	77.9 (0.096)	370 (10.48)	9.75	1.37 (3.48)	156.9 (0.193)
3-Upper Garden Pass Creek	1877 (760.2)	320 (9.06)	3.00	0.61 (1.55)	95.4 (0.117)	462 (13.08)	9.75	1.26 (3.20)	197.1 (0.242)
4-Upper Central Garden Pass Creek	6099 (2470.1)	1257 (35.60	3.50	0.79 (2.01)	401.5 (0.494)	1639 (46.42)	10.00	1.51 (3.84)	767.5 (0.944)
5-Upper Tyrone Creek	449 (181.8)	179 (5.07)	2.75	1.31 (3.33)	49.0 (0.060)	176 (4.98)	9.50	2.16 (5.49)	80.8 (0.099)
6-Lower Tyrone Creek	4273 (1730.6)	1415 (40.07)	3.00	1.22 (3.10)	434.4 (0.534)	1515 (42.90)	9.75	2.05 (5.21)	730.0 (0.898)
7-Central Garden Pass Creek	10372 (4200.7)	2634 (74.59)	3.25	0.97 (2.46)	838.4 (1.031)	3154 (89.32)	10.00	1.73 (4.39)	1495.3 (1.839)
8-Lower Garden Pass Creek	12295 (4979.5)	3241 (91.79)	3.50	1.02 (2.59)	1045.1 (1.285)	3807 (107.81)	10.00	1.80 (4.57)	1844.2 (2.268)
9-Upper Northeast Kobeh Valley #1	1643 (665.4)	415 (11.75)	3.25	0.94 (2.39)	128.7 (0.158)	498 (14.10)	9.75	1.72 (4.37)	235.5 (0.290)
10-Lower Northeast Kobeh Valley #1	3239 (1311.8)	809 (22.91)	3.25	0.91 (2.31)	245.6 (0.302)	978 (27.70)	9.75	1.68 (4.27)	453.5 (0.558)
11-Upper Northeast Kobeh Valley #2	699 (283.1)	226 (6.40)	2.75	1.09 (2.77)	63.5 (0.078)	246 (6.97)	9.50	1.90 (4.83)	110.7 (0.136)

Source: Hydro-Search, Inc., 1983

Annual maximum discharge records for streams in the Garden Pass Creek watershed were reviewed in the HSI Phase I study to confirm the validity of design storm runoff estimates as computed by the SCS method. The records were reviewed during the HSI Phase II study for the same purpose, incorporating the additional 1981 and 1982 data into the analysis.

The Phase II estimates calculated by HYMO were in general agreement with the statistically-derived estimates in the Phase I report. The Phase II design storm runoff estimates by the SCS runoff and VTT routing methods are considered to be representative of extreme events in the Mt. Hope area.

The Phase II results are representative of the magnitude of design storm flows given the level of sophistication of surface water modeling performed and the limited hydrologic data available.

The significance of impacts relative to flood plain development and/or alteration resultant of implementing the proposed action and/or alternatives is primarily based on three concerns: 1) creation or extension of flood plain areas so as to effect down-gradient lands or population; 2) safety factoring of flood plain contingency in tailings dam design; and, 3) creation or extension of flood plain areas so as to effect up-stream lands or population (or in the case of the Mt. Hope project, process plant complex).

Detailed analysis (e.g., Hymo computer modeling) of downstream flood plain effects has not been conducted for the Mt. Hope project. The early stage efforts of engineering design have not provided the detailed diversion system plans necessary for analytical purposes. Several basic design features of the anticipated erosion control, surface water runoff diversion and tailings dam maintenance systems are known, however, which do provide a basis for impact assessment on a worst-case basis. First, tailings dam design and construction would require State of Nevada Engineer and Nevada Department of Wildlife permit approval (NRS 535.010). As such, appropriate engineering and hydrologic control design data would be required prior to permit approval and would be subject to regulatory scrutiny for appropriately stringent prevention of hydrologic impacts of significance. On a worst-case basis, it has been determined that upstream catchment basins would be required to assure adequate retention capabilities

(for both flood water control and sedimentation control purposes) and that downstream water control structures would be required for appropriate runoff diversion confinement. Downstream requirements could include extensive riprapping of stream channels, reconstruction of stream channels, and adequately engineered flood control culverting at or proximal to State Route 278. It is anticipated that the requirements for such flood control would limit the area affected to within the proposed land acquisition boundary area and, on a worst-case basis, would entail major activity to preclude significant impacts to the area in the vicinity of State Route 278. Significant impact, either upstream or downstream, has not been assigned to the flood plain analysis however, as the requirement for permit approvals was considered sufficient to preclude such impact and provide the adequate design and mitigation planning as a result of regulatory agency approval.

Preliminary engineering design of the tailings dam and impoundment area has included considerations of flood plain effects for both siting and design parameters. As in the case of upstream/downstream flood control, dam design safety factoring with flood plain criteria would also be subject to regulatory scrutiny and final approval. As such, a worst-case basis of analysis was determined not to be necessary and a decision of no significant impact was applied.

Potential impacts relative to flood plain criteria applied to the alternative tailings pond areas (Alternates 4-B and 4-C, Figure 1-4) would be of the same magnitude as those described for the proposed action. Tailings pond Alternate 4-B siting characteristics effectively preclude alteration of the existing hydrologic surface system in that its enclosed structure design and low topographic surroundings limit the potential for change. As anticipated for Alternate 4-A, the Kobeh Valley sited Alternate 4-C would require sufficient engineering design to appropriately assure control of maximum precipitation events affecting its drainage area, including the potential for impact presented by the several ephemeral drainage courses emanating from the foothills south of Mt. Hope. Lack of detailed flood plain analysis, however, limits the assessment of impact to one requiring an assumption of complete and mitigative regulatory design review and permit review.

3.4 Mine Pit Inflow

Because of the depth and areal extent (700 acres) of the proposed mine pit, a potential for significant mine water inflow exists since the pit would eventually intersect the underlying groundwater system.

Water in the wall rock of an open pit mine would affect the mine in a number of ways:

1) milling operations could be affected when ore water content is a consideration;

2) an appreciable flow of water into the pit would usually be associated with adverse effects on operations; and

3) the presence of water in the pit walls might contribute to wall instability.

The groundwater level in the pit area is estimated to be at an elevation of 6,400 ft based on groundwater levels in adjacent valleys and on a well east of the mine area (Hydro-Search, Inc., 1982).

Perched water could exist above 6,400 ft and could be within 50 - 100 ft (15.3 - 30.5 m) of the surface. However, perched water would not be capable of sustained inflow to the proposed pit due to a lack of connection with a major replenishment source and limited recharge (precipitation fracture infiltration).

Call and Nicholas, Inc. (1982), in evaluating Hydro-Search data for the mine site, analyzed slope design interior as follows:

"Unlike the operational impact, which is directly related to quantity of inflow, slope stability is primarily related to pore water pressure. Generally, a large inflow of water, especially if it is distributed uniformly around the pit, indicates high effective permeability, free drainage and negligible pore pressure development. Conversely, the absence of an appreciable quantity of inflow, particularly in areas where localized groundwater recharge

is moderate to heavy, or the presence of non-uniformly distributed inflow are indications that the wall rock is not freely draining and that significant pore pressures may exist.

At this time, data are insufficient to allow prediction of the magnitude and distribution of pore pressures within the walls of the proposed pit. Above the 6,400 ft elevation, slopes are expected to be dry. Below 6,400 ft the water table is expected to be in a normal drawdown condition, as illustrated in Figure 3-1. Design analyses were performed assuming negligible pore pressures, i.e., dry slopes, either naturally or artificially drained. The pore pressure does not usually affect individual bench stability; however, it does have an impact on the multiple bench failures defined by major geologic structures. If the structures do not define a potential failure, then there is little need to drain the slopes.

The five-year pit plan has been revised since completion of the Hydro-Search study. Based on the most recent mine plan provided by EXXON (October, 1982), at the end of the five years the pit bottom would be at a 6,400 ft elevation, or below the project water table. Consequently, hydrologic investigation and formulation of de-watering plans cannot be deferred, but must be defined early in the life of the mine.

Based on data, it was estimated that inflow to the pit after 14 years of operation could range from 1.5 to 3.8 M^3/M (400 to 1,000 gpm) with a best estimate of about 2.6 M^3/M (700 gpm). Approximately 1.2 to 2.7 M^3/M (325 to 722 gpm) of the total flow would derive from lateral inflow (depending on transmissibity of the wall rocks) and 0.1 to 0.9 M^3/M (25 to 249 gpm) from vertical flow through the bottom of the pit from the Eastern Assemblage rocks at depth.

Inflow to the pit after 20 years was estimated at 2.6 to 14 M^3/M (700 to 3,700 gpm) with a best estimate of about 8.3 M^3/M (2,200 gpm). Approximately 1.9 to 8.2 M^3/M (514 to 2,160 gpm) of the total flow would derive from lateral inflow and 0.6 to 5.8 M^3/M (152 to 1,522 gpm) from vertical flow through the pit bottom. Data concerning the possible direct interconnection of the Eastern Assemblage carbonates (at depth) with the wall rocks of the proposed pit via fracturing or faulting were not available. Such data would allow further

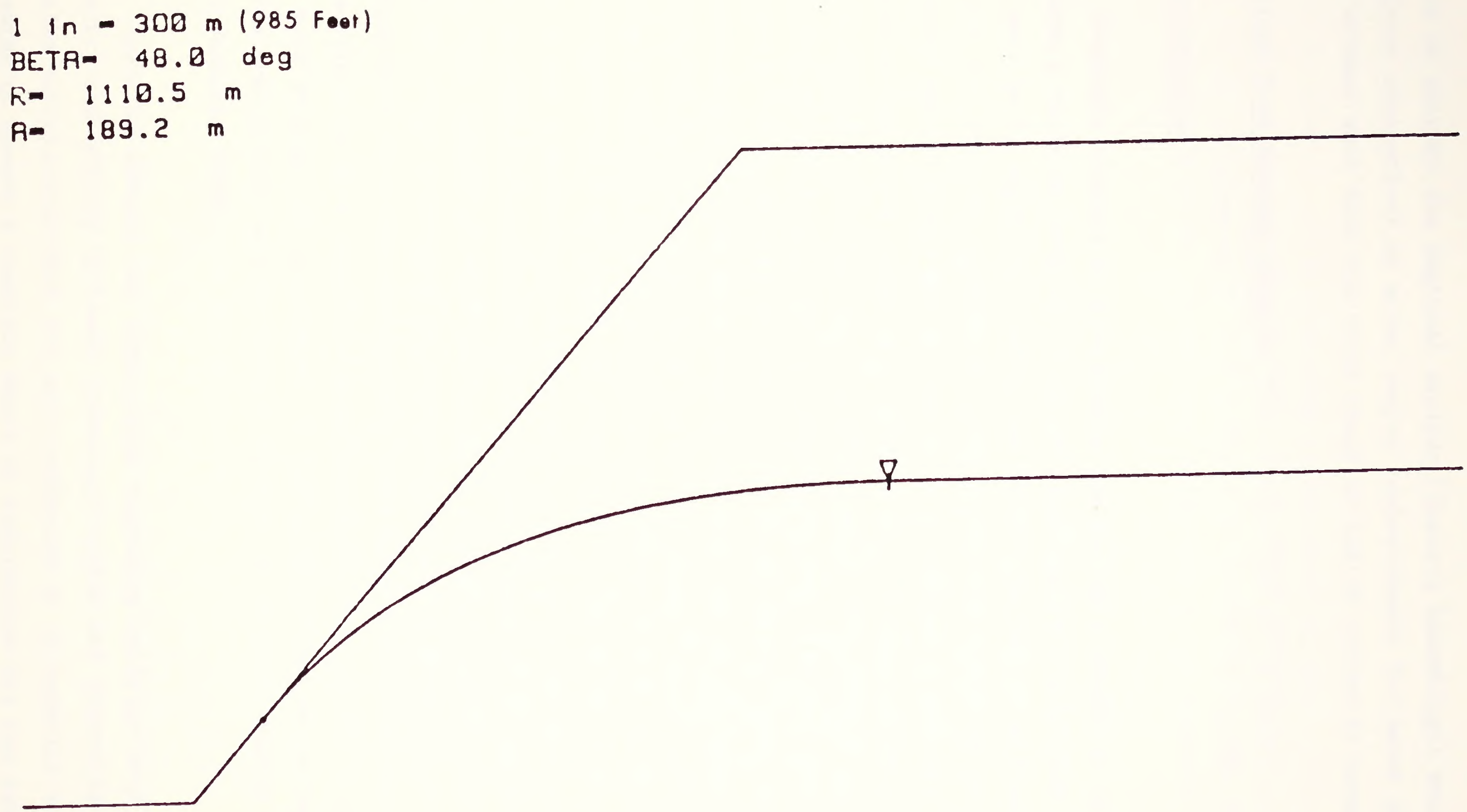


FIGURE 3-1 MINE PIT INFLOW DRAWDOWN

evaluation of whether the regional aquifer (Eastern Assemblage) would act as a major (direct connection) or minor source replenishment for water pumped from the pit; without such data the broad range of inflow values is necessary.

3.5 Tailings Pond Seepage Impacts

3.5.1 Introduction

Possible changes in groundwater quality as a result of effluent seepage from a tailings pond are of significant importance in impact assessment, as well as in regulatory review and permit adequacy. As discussed in Section 3.3, any eventual design and construction of a tailings pond for Mt. Hope activity would be required to undergo the regulatory scrutiny of the Nevada State Engineer and Nevada Department of Wildlife. A major criterion of review by the agencies would involve the characterization of potential seepage, including seepage rates, quality and hydrologic regime effects. As the agencies are mandated by state statute to assure protection of the receiving groundwaters and/or surface waters, the regulatory review must assess not only the effects and potential for mitigation of a proposed action but also the viability of alternatives (e.g., synthetic pond liner, alternate siting) but also the refusal of permit approval. While such review procedures and decisions would be formerly initiated at the time of permit application receipt, the preparation of this Mt. Hope EIS includes detailed analyses and assessment which is additionally subject to NEPA compliance and environmental impact assessment review by a multitude of authorizing agencies, including the Nevada State Engineer and Nevada Department of Wildlife. As such, this section has been prepared not only to address the environmental issues of regulatory concern relative to tailings pond seepage and maintenance of hydrologic resources protection but to present the public body with assessment details of concern (Public Scoping Comments, January, 1983).

Specific details and conclusions regarding tailings pond seepage rate, quality and effects to these hydrologic regime are presented in detail. The detailed calculations have not been presented as an appendix but appear in the following to assure a complete basis of information for the reviewer.

3.5.2 Project Review

Approximately 44 acre-feet (10,123 gpm) of water would be discharged daily from the mineral processing plant to the tailings pond. Most of this water would be returned to the mill for reuse; some would be evaporated and a small portion of the pond water would percolate downward into the subsurface and enter the groundwater system beneath and peripheral to the tailings pond.

Some of the percolating groundwater would be retained in small pore spaces in the unsaturated alluvium beneath the pond and the remainder would continue downward to the water table. The long-term influence of seepage water from the tailings pond that reaches and enters the groundwater system is of particular concern in assessing pond impacts (see Section 3.5.3).

Alluvium beneath Alternate 4-A (proposed site) has a water table that ranges in depth from 29 to 31 feet (Wahler and Assoc., 1983). The underlying bedrock has a low to moderate hydraulic conductivity (ability to conduct water). Although detailed hydrogeological studies or hydraulic tests have not been conducted at Alternate 4-A, sufficient characterization is available to allow estimation of seepage and direction of seepage flow (e.g., eastward toward the Diamond Valley, as at the present time).

Based on a comparison with other tailings pond sites, seepage from Alternate 4-A is estimated to be about 1,000 gpm (Wahler and Assoc., 1983). An estimation of seepage also can be made by assuming 100 acres of active pond in the tailings impoundment; a subsurface permeability of 10^{-5} cm/sec and a unit hydraulic gradient. This results in a calculated pond seepage of 260 gpm. For purposes of impact analysis a seepage of 1,000 gpm has been assumed. Initial seepage would be greater until unsaturated pore spaces beneath the pond were filled and a groundwater flow system developed.

Alternate 4-B in the Diamond Valley would also be underlain by alluvium with a relatively shallow water table. No detailed hydrogeological investigations or tests have been conducted on this site. Seepage from this pond has been assumed to be the same as for Alternate 4-A, that is, about 1,000 gpm. Seepage from Alternate 4-B would create a groundwater "mound" (in pressure)

beneath and peripheral to the pond. The present direction of groundwater movement from Alternate 4-B is northeastward toward the valley center. Seepage water from the pond would follow this general flow path.

Alternate 4-C in Kobeh Valley would be underlain by alluvium that probably attains a thickness of several hundred feet. Deeper alluvium is coarser than the surficial silty materials and is likely to have a seepage rate similar to the other ponds. Any seepage from the pond would establish a radial flow pattern and move downgradient from the pond. Depth to groundwater at this site has not been determined. The direction of groundwater flow in the area of Alternate Site 4-C is south or southwestward into the valley center (Hydro-Search, Inc., 1982).

After entering the subsurface, physical and chemical processes would alter the tailings water quality. Adsorption, ion exchange, precipitation, dissolution of minerals, dilution and dispersion are some of the physical-chemical processes that would modify the quality of seepage water. The following sections detail anticipated seepage effects.

3.5.3 Derivation of Tailings Pond Seepage Rate

The estimation of seepage rate during operation required the following assumptions:

1) Seepage flow would be steady state and Darcy's Law would be satisfied. Darcy's Law is expressed as follows:

$$Q = k_v ia$$

where Q = vol/unit time, m^3/sec

K_v = coefficient of permeability, ^{cm}/sec

A = area, $m^2 x 10^6$

i = hydraulic gradient, dimensionless

2) Seepage through the overflow slimes once deposited would be vertical and under unit gradient flow.

3) Natural basin soils are of high enough permeability as to offer no restriction to flow relative to the tailing slimes.

4) Water residing within the sand tailings will seep into the confines of the pond and collect in the reclaim pool; therefore, seepage loss from the sands will be minimal. Dusting of the sand area will be controlled by intermittent covering with a thin layer of overflow slimes thus further minimizing vertical seepage potential.

5) In accordance with the tailing pond management plan, the following percentages of the pond would be occupied by the various materials:

Cyclone Sands	- 25%
Reclaim Lake	- 20%
Overflow Slimes	- 55%

6) Coefficient of permeability of overflow slimes would range between 3×10^{-7} and 8×10^{-7} cm/sec. (Source: EXXON Minerals Company)

7) The average reclaim lake depth would be 2.5 meters (8.25 feet).

For the listed assumptions, two cases were evaluated to estimate an upper and lower bound of pond seepage rate.

Case I - Maximum Seepage

To calculate seepage from the lake area, Q_1,

depth of pool = 2.5m

thickness of slimes under pool = 0.5m

i = 6.0 (hydrologic gradient)

a = 0.2 (total pond area with time)

$K_v = 8 \times 10^{-7}$ cm/sec (coefficient of permeability)

To calculate seepage from the overflow slime area, Q_2,

i = 1.0

a = .55 (total pond area with time)

$K_v = 8 \times 10^{-7}$ cm/sec

Total seepage, $Q_3 = Q_1 + Q_2$

The change in seepage volume with time and relative contribution of the reclaim lake and overflow slimes are shown below.

Time (in Years)	Area (m^2xq10^6)	Seepage Contribution Lake-Q_1 (m^3/sec)	Tailings-Q_2 (m^3/sec)	Total-Q_3 (m^3/sec)
2	1.25	1.2×10^{-2}	5.5×10^{-3}	1.7×10^{-2}
5	2.25	2.2×10^{-2}	9.9×10^{-3}	3.2×10^{-2}
10	3.70	3.5×10^{-2}	1.6×10^{-2}	5.1×10^{-2}
15	4.80	4.6×10^{-2}	2.1×10^{-2}	6.7×10^{-2}
20	5.85	5.6×10^{-2}	2.6×10^{-2}	8.2×10^{-2}

Case II - Minimum Seepage

To calculate seepage from the lake area, Q_1,

Depth of pool = 2.5m

Thickness of slimes under pool = 0.5m

i = 6.0 (hydraulic gradient)

a = 0.2 (total pond area with time)

K_v = 3 x 10^{-7} cm/sec (coefficient of permeability)

To calculate seepage from the overflow slime area, Q_2,

i = 1.0

a = 0.55 (total pond area with time)

K_v = 3 x 10^{-7} cm/sec

Total seepage, $Q_3 = Q_1 + Q_2$

		Seepage Contribution		
Time in Years	Area (m^2x10^6)	Lake-Q_1 m^3/sec	Tailings-Q_2 m^3/sec	Total-Q_3 m^3/sec
2	1.25	4.5 x 10^{-3}	2.06 x 10^{-3}	6.6 x 10^{-3}
5	2.25	8.1 x 10^{-3}	3.71 x 10^{-3}	1.2 x 10^{-2}
10	3.70	13.3 x 10^{-3}	6.10 x 10^{-3}	1.9 x 10^{-2}
15	4.80	1.72 x 10^{-2}	7.90 x 10^{-3}	2.5 x 10^{-2}
20	5.85	2.10 x 10^{-2}	9.6 x 10^{-3}	3.1 x 10^{-2}

The conclusions reached by the operational seepage calculations of Case I and Case II indicate that the maximum seepage at year 20 is not anticipated to exceed 8.2 x 10^{-2} (Case I) m^3/sec (1308 gpm) and possibly will not exceed 3.1 x 10^{-2} m^3/sec (491 gpm). For all practical purposes the anticipated seepage at year 20 has been estimated to range from 500 to 1,000 gpm. The latter figure was used for the purpose of worst-case analysis.

The estimation of seepage rate after reclamation required a two-step process: (1) calculation of total volume of water remaining in the tailings, and (2) calculation of amount of time it would require that finite volume to seep from the tailings pond. To perform the calculations, the following assump-

tions were made:

1) The only available drainable water would be from cyclone overflow materials estimated to occupy 55% of total basin area.

2) The estimated depth of tailings in basin (average) for ultimate 650 million tonnes (728 million tons) of tailings would be 120m x 2/3 or 80 meters (262 feet).

3) The final basin area would be 14.8×10^6 m^2 (17.7 yd^2)
The ultimate storage volume would be 446×10^6 m^3 (583×10^6 yd^3)

$$650 \times 10^6 \text{ tonnes (Total Reserve)} - 42.5 \times 10^6 \text{ tonnes (Sand for Dam)} = \frac{607.5 \times 10^6 \text{ tonnes}}{1.36 \text{ t/m}^3} = 446 \times 10^6 \text{ m}^3 \text{ (Storage Volume)}$$

The total volume of drainable tailings is the product of the total impoundment volume and the volume occupied by cyclone overflow materials or 446×10^6 $m^3 \times 0.55 = 245 \times 10^6$ m^3 of total drainable tailings volume (from which seepage after reclamation would occur).

The total drainable volume of water was calculated as follows:

For a unit volume of soil, the percent saturation is defined by:

$$\%S = \frac{Vw}{Vv}$$

where Vw = Volume of voids occupied by water

Vv = Volume of voids (air and water)

where $V_v = V_t - V_s$

$V_t = V_v$ the total volume of voids (air and water) plus V_s (Volume of soilds) is the total volume

$$V_s = \frac{Ws}{G_s \cdot 62.4 \text{ pcf}} \quad \text{(Volume of solids)}$$

where W_s is the weight of solids in pounds
G_s is the specific gravity in gm/cc or ton/m^3

For following assumed set of material properties measured relative to other fine tailings.

G_s = 3.34gm/cc and W_s = 105 pcf (1.68 t/m^3),

The volume of solids (V_3) was calculated to be 0.504 ft^3/ft^3.

To calculate V_w (Volume of water in the Void Space) the weight of water (W_w) was first calculated by $W_w = w \cdot W_s$ where w equalled the moisture content, i.e., 25% (determined from a moisture/suction drying curve) and W_s equalled the weight of solids (in this case the dry unit weight of 105)).

Thus the weight of water (W_w) equalled 26.25 lbs (0.25 x 105) and the volume occupied by 26.25 lbs of water (V_w) equals 26.25 (W_w)/62.4 or 0.421.

The percent of saturation at field storage capacity was then determined to be:

$$\%S = \frac{V_w}{V_v} = \frac{.421}{.496} = 0.848 \text{ or } 84.8\%$$

The percent saturation of 84.8 percent is for a 25% moisture control level and is therefore the field capacity (Fc). For a silty to sand loam F_c = 75 to 85% for analytical purposes, a field capacity (Fc) equalling 85 percent was selected.

For a unit volume of Mt. Hope tailings with a specific gravity (Gs) of 2.65 and an average e of 0.90 where e is the void ratio defined as:

$$e = \frac{V_v}{V_s} = \frac{0.474}{0.526} = 0.90$$

where V_v = volume of voids and V_s = volume of solids

Assuming that the tailings would initially be totally saturated (S = 100%), the weight per unit volume of potential drainable water would equal 0.474 x 62.4 or 29.6 pcf (0.474 tonne/m^3). Using a field capacity saturation of 85%, the actual amount of drainable water per unit volume would be reduced to (1-0.85) (0.474 t/m^3) or 0.071 t/m^3.

Total drainable water from fine tailings would then equal 17.4 x 10^6 tonnes (0.071 x 245 x 10^6 m^3).

The time required for drainable water to seep from the pond was thus determined by the following:

.071 t/m^3 = drainable water per unit volume

80m = average depth of tailings

Total drainable water per unit area = 0.071 t/m^3 x 80m = 5.68 m^3/m^2 or 5.68 t/m^2

at $k_v = 8 \times 10^{-9}$ m/sec $T = \frac{5.68}{8 \times 10^{-9}} =$ 22.5 years (maximum seepage - Case I)

at $k_v = 3 \times 10^{-9}$ m/sec $T = \frac{5.68}{3 \times 10^{-9}} =$ 60 years (minimum seepage - Case II)

Thus, retained water in the tailings pond material has been estimated to finalize seepage pathways in 22 to 60 years. The net effects of such water retention and gradual release via seepage depend primarily on the overall, chemical quality of the waters released (Section 3.5.4). The above calculations of drainable water do not include consideration of precipitation contributions

which, due to reclamation planning (e.g., sloping to enhance surface water run-off, vegetation planting and soil placement), would primarily not represent a source of seepage water since most, if not all losss of water would occur via evaporation, evapotranspiration and as peripheral surface water runoff.

3.5.4 Derivation of Tailing Pond Seepage Quality

The Mt. Hope concentrator would initially use groundwater from Kobeh Valley, but as the process matured and tailings were generated, recycle of tailings water would occur. At steady state, the quality of this recycle water would be approximately the same as the quality of seepage from the tailing pond.

There are four factors that would affect recycle water quality:

1) reagents added to the mill circuit;
2) chemicals species leached from the ore in the mill circuit;
3) chemical species leached from the solid fraction of the tailing, and
4) water balance.

The contribution of the first two factors to steady state was estimated based on laboratory metallurgical tests, the results of which are summarized in Table 3-2. Dissolution of the solid fraction (Factor 3) would not affect all constituents. Those that would be affected have been estimated by EXXON based on the operating experience of other molybdenum mines. These facilities have apparently experience build-up of the constituents listed in Table 3-3.

The fourth factor, water balance, has been estimated to be that shown in Figure 3-2. The tailing pond would experience a net evaporation tending to further concentrate the dissolved constituents. At the same time, water lost to seepage and stored in tailings pond water would represent a bleed from the overall system.

The following explains the derivation of the concentration estimates for those parameters that would build-up as a result of tailings dissolution. The information has been provided primarily from EXXON Minerals Company.

Table 3-2 Estimated Composition of Aqueous Fraction of Tailings

Element	Concentration After Eight Cycles (ppm)	Estimated Equilibrium Concentration (ppm)[1]
Ag	0.01	
Al	0.16	
As	<0.063	
B	0.012	
Ba	0.058	
Be	**	
Ca	40.0	
Cd	0.0091	
Co	**	
Cr	0.0068	
Cu	0.0041	<1.0
Fe	0.21	1.0
K	58.1	
Li	0.058	
Mg	11.04	
Mn	0.278	5.0
Mo	1.083	<2.0
Na	48.54	
Ni	0.0068	
P	1.611	
Pb	**	
Pt	**	
Sb	**	
Se	**	
Si	3.58	
Sn	1.26	
Sr	0.08	
Ti	**	
Tl	**	
U	**	
V	**	
W	**	
Zn	0.035	<1.0
Cn-	1.858	1.0
Total Sulfur	94.5	
$SO_4=$	86.9	500
$CO_3=$	0.65	
HCO_3-	159.7	
TOC	17.24	
TDS	621.0	1000
pH	--	6-8

** Below detectable limit.

1 First column represents laboratory results of metallurgical testing using Kobeh Valley water recycled eight times. For most constituents these estimates approximate equilibrium concentrations. Those constituents which may further build up are shown in the second column with the extent of build-up having been estimated based on operating experiences at other similar molybdenum processing facilities.

Source: EXXON Minerals Company

Table 3-3 Tailings Pond Constituent Concentrations Associated With Other Molybdenum Facilities1/

	Fe	Mn	Cu	Zn	Mo	CN	Ca	HCO_3	SO_4	pH	TDS2/
Facility #1	1.5	4.3	0.4	0.05	21	0.67	500	69	10003/	N/A	20003/
Facility #2	0.15-0.4	4.6-7.2	0.07	N/A	1.9	0.05-0.23	N/A	N/A	11004/	7.1	2400

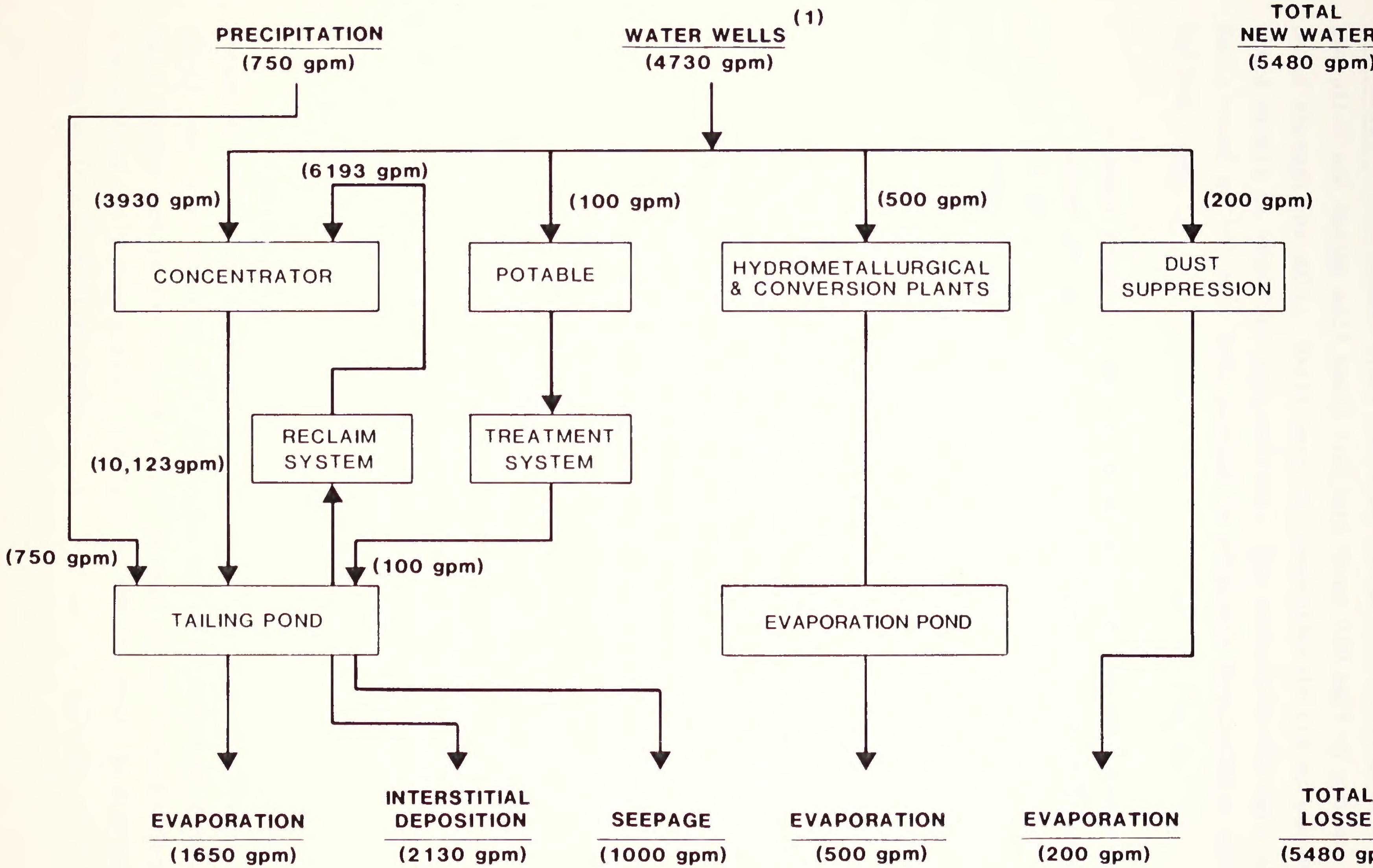
1/ All figures are in mg/l except for pH; facility sources considered confidential.

2/ TDS = Total Dissolved Solids.

3/ Calculated based on Ca + HCP_3 analysis.

4/ SO_4 level was 500-600 ppm in 1978.

Source: EXXON Minerals Company



(1) EXXON HAS A WATER APPROPRIATION OF 5400 gpm IN KOBEH VALLEY. THIS BALANCE SHOWS AN UNPUMPED RESERVE OF 670 gpm.

SOURCE: EXXON MINERALS COMPANY

MT. HOPE MOLYBDENUM PROJECT

PROVISIONAL WATER BALANCE AT YEAR 20

U.S. Department of the Interior
Bureau of Land Management

FIGURE 3-2

TDS/Sulfate. The locked-cycle flotation tests and the reagent consumption in the pilot and design mill would indicate about 100 mg/l of sulfate for each cycle through the mill. Water recycle, approximately 60% at steady state, would equate to about 300 mg/l sulfate. The additional 200 mg/l of sulfate for a total of 500 mg/l were assumed to originate from sulfide oxidation in tailing pond.

- Nokes reagent (P_4S_5 and NaOH) would be the only source of sulfur added during the flotation of molybdenite. An additional rate of 29 g/t for P_4S_5 equates to 26 mg/l of $2O_4$ equivalent in discharged tailings slurry (35% solids).

- $SO_4 = \frac{5S}{P_4S_5} \times 29 \times \frac{35}{65} - 26$ mg/l

- The rougher float water in the 8 cycle locked flotation tests would not have Nokes reagent added. Thus, any sulfur present would come from the ore. The sulfate equivalent in the rougher water would be 280 mg/l = 93.4 x 96/32. The steady state value of 280 mg/l of sulfate equivalent would equate to about 50 mg/l per cycle as the result of fresh water addition during each locked-cycle flotation test.

- The large fraction of non-sulfate sulfur in both rougher and cleaner water samples would result from little time for oxidation to sulfate between flotation cycles as would exist in an actual mill where mill water is aged in tailing pond before recycle back to the mill.

From published and inferred data on the reagent consumption and the extent of water recycle, it can be projected that for the TDS/SO_4 at least 75% would come from oxidation of sulfides, principally pyrite to sulfate in the mill circuit and in the tailing pond. Because of the long residence time and the wetting and drying cycles, the bulk of TDS/SO_4 would be a result of sulfide oxidation in the tailings pond.

- Nokes reagent would contribute 26 mg/l per pass through the mill. At steady state and 80% recycle at Facility #2 this would equate to 125 mg/l SO_4. The remaining sulphate of nearly 1000 mg/l would be generated by sulfide in the ore.

Both Facility #1 and Facility #2 ores are richer in molysulfide and other sulfides and thus less sulfate generation from the Mt. Hope ore would be expected.

The balance cation is likely to be sodium and to a lesser extent calcium. Calcium should be controlled to some extent by the alkalinity in the cleaner circuit and the high bicarbonate content of the Mt. Hope well water.

Metals. Iron, manganese, copper, zine and moly will build up due to water recycle but would eventually be limited by solution-mineral solubility constraints.

Cyanide. Cyanide would only be present because of its addition as a mill reagent. Cyanide would be subject to photochemical oxidization and destruction in the tailings pond so the equilibrium concentration would depend upon extent of recycle, residence time in the tailings pond and climatic conditions. As Table 3-2 indicates, the estimated equilibrium concentration would equal 1.0 ppm.

3.5.5 Toxicity Testing Results

As part of the environmental analyses necessary to evaluate the impacts of tailings disposal, an EPA toxicity testing procedure was conducted on test material to determine degree of regulatory specified toxicity and potential of the tailings for acid-producing conditions. A synopsis of the testing results is presented in the following sections.

As summary to the following test results, the tailings material was determined not to present a toxicity problem of adverse significance. While the tailings material represents a net acid-producing condition, mitigation measures of pond reclamation and surface water runoff diversion were determined to effectively mitigate the potential for long term effects (e.g., no adverse significance).

3.5.5.1 Experimental Procedures

Acid Producing/Consuming Tests

- Five percent by volume of each slurry was taken: 280 ml from scavenger tailings. 250 ml from first cleaner scavenger tailings. 126 ml from second cleaner scavenger tailings.

  Note: Volumes of the three tailings samples mentioned above do not reflect the actual volume proportion of the tailings coming out of the proposed flowsheet. In reality the volume of the scavenger tailings should be four times that shown above. At four times higher scavenger tailings volume, the acid producing capability would decrease to 19.2 pounds H_2SO_4 per ton of solid tailings, and acid consuming potential would increase proportionately.

- The slurry was mixed well and filtered to obtain a composite tailings sample.

- Four 7-gram samples underwent sulfur analysis.

- Four 12-gram samples were suspended in 100 ml distilled water and stirred for 15 minutes.

- Natural pH of the sample was recorded.

- The samples were titrated to pH 4.5, 4.0, 3.5, 3.0 with 1.0 Normal H_2SO_4. The titration was continued until less than 1 ml acid was added over a 30 minute period.

- The volumes of the acid added were recorded.

- The amount of acid consumed was converted to pounds of H_2SO_4/ton of tailings sample.

- The acidic solution generated from four tests were analyzed for Cu, Pb, Zn and Fe.

- Weight of dry residues was recorded.

EPA Toxicity Test

- The test sample for this study was the same as that used in the acid consuming and producing tests. A 130 gram wet (15.7% moisture) sample of the tailings was taken. Solids Weight = 109.6 gram.

- Assuming 30% slurry was taken from the flotation cell, 256 ml of filtrate was taken and saved.

- The solids were put in an extractor with sixteen times their weight of deionized water. Amount of deionized water added was 1,753 ml. The solids were not allowed to dry.

- Agitation was begun and the pH was measured. Since the pH was greater than 5.0, the pH was decreased to 5.0 $\pm$ 0.2 by adding 0.5 Normal acetic acid.

- The slurry was agitated for a 24-hour period.

- At the end of 24-hour period, deionized water was added to the extractor. The amount of water to be added was calculated according to:

  $V = 20W-16W-A$

  where V = ml of deionized water to be added
  W = weight of solid in grams
  A = amount of acetic acid added in ml

- The material in the extractor was separated into liquid and solid phases by filtration.

- The liquid was combined with the 256 ml filtrate that was in the original tailings. 250 ml of the solution was submitted for analysis of those elements listed.

3.5.5.2 Experimental Data and Calculations

Acid Producing/Consuming Tests

Third cycle scavenger
tailings = 580 ml
Cleaner scavenger tailings #1 - 250 ml
Cleaner scavenger tailings #2 - 126 ml

Acid Producing Capability:

Sulfur assay of four samples
(7 grams each)

1. 0.49 percent
2. 0.49 percent
3. 0.49 percent
4. 0.47 percent

Average sulfur = 0.485%

Basis: one ton of solid residue

Amount of sulfur (grams) in one ton
tailings =

$$1{,}000 \text{ kg} \times \frac{0.485}{100} = 4{,}850 \text{ grams}$$

Assuming one mole of sulfur produces one mole of H_2SO_4, 4850 grams sulfur will produce

$$= \frac{4,850 \times 98}{32 \times 454}$$

= 32.7 pounds of H_2SO_4 per ton of solid tailings (Note: It estimated that this number would decrease to 19.2 under the assumption of the proposed action).

Acid Consuming Potential:

Four 12-gram samples were taken at moisture content = 15.72% (12 x 0.1572 = 1.8864 grams water)

Weight of Sample = 12 grams - 1.9 grams = 10.1 grams

pH = 4.5

The amount of 1.0 Normal sulfuric acid consumed to lower the pH to 4.5 = 0.5 ml (initial pH = 9.32)

pH = 4.0

The amount of 1.0 Normal H_2SO_4 consumed to lower the pH to 4.0 = 0.6 ml (initial pH = 9.28)

pH = 3.5

The amount of 1.0 Normal H_2SO_4 consumed to lower the pH to 3.5 = 0.7 ml (initial pH = 9.22)

pH = 3.0

The amount of 1.0 Normal H_2SO_4 consumed to lower the pH to 3.0 = 0.9 ml (initial pH = 9.25)

Acid Consuming Ability

at pH 4.5 =

$$\frac{0.5 \text{ ml} \times 0.049 \times 2{,}000}{10.1 \text{ grams}} = 4.8 \text{ lb/ton}$$

at pH 4.0 =

$$\frac{0.6 \text{ ml} \times 0.049 \times 2{,}000}{10.1 \text{ grams}} = 5.8 \text{ lb/ton}$$

at pH 3.5 =

$$\frac{0.7 \text{ ml} \times 0.049 \times 2{,}000}{10.1 \text{ grams}} = 6.8 \text{ lb/ton}$$

at pH 3.0 =

$$\frac{0.9 \text{ ml} \times 0.049 \times 2{,}000}{10.1 \text{ grams}} = 8.7 \text{ lb/ton}$$

These numbers could be higher if scavenger tailings volume in the sample is increased by four times. The acidic solution generated from four tests were analyzed for Cu, Pb, Zn and Fe (Table 3-4).

<u>EPA Toxicity Test</u>

Amount of wet tailings = 130 grams at 15.7% moisture

Solids weight = 109.6 grams

Water added = 1,753 ml

At Time (t) = 0, initial pH = 9.46

Amount of acetic acid added = 37 ml

Amount of water added V = 20 (109.6) - 16 (109.6) - 37 = 401.4 ml

Table 3-4 Acid Consuming Potential of the Flotation Tailings from the Major Composite

Acid Consuming Potential (lb H_2SO_4/ton Tailings)	pH	Acid Solution Assay, ppm Cu	Pb	Zn	Fe	Weight of Residue, grams
4.8	4.5	0.2	N.D.	1.0	4.9	10.9
5.81	4.0	0.2	N.D.	1.6	18.8	9.9
6.8	3.5	0.2	0.2	1.6	20.0	9.9
8.7	3.0	0.5	0.2	3.0	28.0	9.9

N.D. Not Detected

Source: EXXON Minerals Company

Table 3-5 indicates comparative review of test results with EPA specifications.

3.5.6 Deriviation of Potential Effects

The following worst-case assumptions were made in analyzing the potential effects of seepage on groundwater in Diamond Valley.

1) There would be no attenuation of constituents; the maximum possible concentrations existing the tailings pond would be those shown in Table 3-2.

2) The rate of seepage would be 1,000 gpm during the 50-year operation phase. After closure, it would require 22.5 years for the remaining volume of tailings liquor to seep (8.34 x 10^5 m^3/yr).

3) There would be no dilution of seepage by Pine Valley groundwater before seepage entered Diamond Valley.

4) Seepage would be forced through Tyrone gap (worst-case Alternate 4-A, proposed action) and would spread in the shape of an equidimensional 100-ft. wedge at the rate of 1,000 ft/yr (assumed worst-case).

5) All groundwater in Diamond Valley (2.8 x 10^6 ac-ft) is equally distributed throughout the valley within the same 100-ft section as the seepage front. There would be equal mixing across the equidimensional wedge, Nevada Division of Water Resources, 1971.

3.5.6.1 Calculation Methodology and Sample Calculation

The following series of calculations was made for each year.

Table 3-5 Composition of the Leach Liquor

Species	This Sample, ppm	EPA Specification, ppm
As	0.06	5.0
Ba	0.92	100.0
Cd	0.042	1.0
Cr	<0.0015	5.0
Pb	<0.02	5.0
Hg	0.2 ppb	0.2
Se	<0.02	1.0
Ag	0.005	5.0

Based on the results, data shown in Table D-2, tailings could be classified as non-hazardous.

Source: EXXON Minerals Company

1) Mass of Seepage Constituent in Diamond Valley: (z_1)(concentration of constituent in seepage (xl) x volume of seepage (yl))

The equation references a cumulative total with each year's contribution added to the sum of the preceeding years.

2) Mass of Constituent Naturally Present in Diamond Valley within the Wedge (z_2): (background concentration of constituent in Diamond Valley = x2) x (volume of Diamond Valley groundwater in wedge = y2)

The equation represents a cumulative total with each year's contribution added to the sum of the preceeding years.

3) Total Mass of Constituent: $z_1 + z_2 = z_3$

4) Total aqueous volume in the wedge: $y_1 + y_2 = y_3$

5) Resulting concentration in Diamond Valley: $x_3 = \frac{z_3}{y_3}$

A sample calculation for year 1, for Zinc, follows

1) (1.0 mg/l) (1.99×10^6 m^3) = 1.99×10^6 gms of zinc in tailing seepage

2) (0.1 mg/l) (1.39×10^5 m^3) = 1.39×10^4 gms of zinc naturally present

3) $1.99 \times 10^6 + 1.39 \times 10^4 = 2.00 \times 10^6$ gms of Zn totally

4) $1.00 \times 10^6 + 1.39 \times 10^5 = 2.13 \times 10^6$ m^3, the total volume

5) $\frac{2.00 \times 10^6}{2.16 \times 10^6} = 0.94$ mg/l

3.5.6.2 Results Summary

Tables 3-6 and 3-7 present in summary from the estimated groundwater constituent concentrations in Diamond Valley resulting from tailings pond seepage and a reference for constituent concentrations (baseline and regulatory), respectively. The analysis of seepage effects was performed only for those constituents that may leave the pond at or above drinking water standards, i.e., copper, iron, manganese, sulfate and arsenic.

Overall groundwater quality in Diamond Valley would be altered. For those parameters that could potentially exceed drinking water standards (Cu, Fe, Mn, SO_4, As, and TDS) at the time of exit, copper and arsenic would have fallen below drinking water standards by year 5, when the seepage from exists the property. Total dissolved solids and sulfate would have fallen below drinking water standards by the conclusion of reclamation. Only iron and manganese, both naturally high, would persist beyond reclamation activities. It is estimated that iron would drop below the drinking water standard in year 100. Manganese concentrations are currently in excess of the drinking water standard and a reduction to levels below those standards is not anticipated.

3.5.7 Impact Summary

As noted, the quality of tailings pond seepage would depend on the quality of the process plant effluent and physical chemical changes to the aqueous fraction of the tailings such as absorption, ion exchange, precipitation, dissolution of minerals, dilution and dispersion. EPA toxicity tests show that the tailings would not be considered hazardous. On the basis of worst-case analysis, parameter concentrations in Table 3-2 are maximum that could eventually be expected to infiltrate into groundwater beneath or adjacent to any of the ponds.

After the seepage water joins the existing groundwater system it would slowly move downgradient eastward into Diamond Valley where it would mix with natural groundwater. As dilution occurred, the influence of pond seepage water on groundwater quality would decrease. Rates of groundwater

Table 3-6 Estimated Groundwater Constituent Concentrations in Diamond Valley Resulting From Tailings Pond 4-A Seepage (mg/l)

Year	Concentration Parameters						Area Affected	% Diamond Valley Area Affected
	Cu	Fe	Mn	SO_4	As	TDS	sq. mi.	
1	0.94 4/	.95	4.7	470	<.059	961	.036	.005
2	0.88	.91	4.4	445	<.055	927	.143	.02
3	0.83	.87	4.1	422	<.052	898	.323	.05
4	0.78	.83	3.9	402	<.049 4/	870	.574	.08
1/ 5	0.75	.80	3.7	386	<.047	849	.897	.13
10	0.60	.69	3.0	317	<.037	757	3.59	.51
15	0.50	.61	2.5	274	<.031	699	8.07	1.2
20	0.43	.56	2.1	241 4/	<.026	657	14.3	2.0
25	0.38	.51	1.9	217	<.023	623	22.4	3.2
30	0.34	.48	1.7	199	<.020	600	32.3	4.6
40	0.28	.44	1.4	173	<.017	566	57.4	8.2
2/ 50	0.24	.41	1.2	155	<.014	541	89.7	12.8
60	0.19	.38	0.96	135	<.011	516	129	14.5
70	0.16	.35	0.80	121	<.009	497 4/	176	19.7
3/ 72.5	0.16	.35	0.81	121	<.009	498	189	21.2
80	0.13	.33	0.66	108	<.007	479	230	25.8
90	0.11	.31	0.55	98	<.006	466	291	32.6
100	0.10	.30 4/	0.47	88	<.005	456	359	40.2

1/ Estimated time for seepage front to exit project boundary area.

2/ End of operation, closure begins.

3/ Estimate time when remaining volume from tailings pond after closure would have seeped from pond.

4/ Year at which national drinking water standards are met. Because background manganese concentrations are already greater than drinking standards, these standards cannot be achieved.

Note: Basic worst-case assumptions are as follows: 1) Maximum seepage rate of 1000 gpm begins immediately and is maintained until closure begins; 2) All seepage is directed through Tyrone Gap; 3) There is no attenuation of seepage; 4) There is no dilution of seepage before reaching Diamond Valley; 5) The seepage front moves at the rate of 1000 ft/year; 6) Groundwater is uniformly distributed throughout Diamond Valley; 7) There is uniform mixing across the seepage front and affected portions of Diamond Valley.

Source: EXXON Minerals Company, WRC EIS Team

Table 3-7 Reference Constituent Concentrations (mg/l)

Parameter	Diamond Valley Baseline Concentrations for Constituents of Interest	Primary & Secondary Drinking Water Standards for Constituents of Interest
Cu	0.02 1/	1.0
Fe	0.24	0.3
Mn	0.09	0.05
SO_4	56	250
TDS	411	500
As	0 2/	0.05

1/ No data on this parameter available for Diamond Valley, Kobeh Valley data transferred.

2/ No data on this parameter available, assumed to be zero.

Source: EXXON Minerals Company, WRC EIS Team

movement range from an estimted 100 to 1000 feet per year. This slow movement would restrict the areal extent of seepage water migration. There is limited groundwater usage near the potential tailings ponds sites.

Based on the above stated estimates and a general but limited knowledge of existing geological and hydrological conditions, a worst-case analysis was required to assess the potential impacts to groundwater quality in Diamond Valley. This analysis detailed in the preceding subsection, is summarized by Table 3-6 which indicate the parameters of chemical constituents which could potentially exceed drinking water standards (Cu, Fe, Mn, SO_4, As and TDS).

Implementation of the monitoring program described in Technical Report No.1 and briefly outlined in Section 3.2 of this Technical Report, as well as the more detailed study of seepage rate and quality that would occur during later stages of project engineering and permitting, will foster a more accurate understanding of the potential effects to groundwater. This information will be used in working with the Nevada Division of Environmental Protection to acquire necessary permits and identify the most appropriate control technology.

Impacts from tailings pond seepage from Alternate 4-B, (Diamond Valley site) would be of the same order of magnitude as that associated with the proposed action. However, because there is no natural barrier to seepage flow (i.e., Sulphur Range), the worst-case analysis would include equidimensional flow in a northeastward direction in Diamond Valley. Impacts associated with Alternative site 4-C (Kobeh Valley site) are also similar except that site 4-C is located within Kobeh Valley and the seepage front would move south or southwestward toward the valley center.

The no action alternative would preclude surface water or groundwater impacts as implementation of the project activity would not occur. Neither the beneficial water use proposed by EXXON or the reduction in evapotranspiration losses (resultant from drawdown in Kobeh Valley) would occur. Regulatory standards for manganese concentrations in groundwater would, however, continue to be exceeded.

3.6 Groundwater Withdrawal Effects

The mining and mineral processing operations of the proposed action and/or alternatives would require a continuous water supply of about 5,480 gpm. Of this, 3,930 gpm would be used in the mineral concentrator; 500 gpm in the hydrometallurgical plant, 200 gpm for dust suppression and 100 gpm for potable use. Water wells in the Kobeh Valley would supply 4,730 gpm and precipitation would supply the remaining 750 gpm. Process water would be lost primarily by evaporation from the tailings pond; some by seepage and some would be retained in the settled tailings.

Three potential sites in Kobeh Valley have been selected as alternative water supply sources. Conceptually, each of the proposed well fields would consist of four production wells with a 1,000 foot spacing. During operation of the well field, two wells would be pumped at a given time with two wells serving in reserve capacity. Production wells would be expected to be about 700 to 800 feet deep and would rely on Eastern Assemblage bedrock as the primary water source. The base of the alluvium also may supply some water.

Kobeh Valley is a structural, fault bounded basin containing a substantial thickness of alluvial valley fill. An appraisal of the overall effect of annually withdrawing 4,370 gpm (7,630 ac-ft per year) from Kobeh Valley can be made on the basis of perennial yield. The perennial yield for Kobeh Valley, as defined by Rush and Everett (1964), is the maximum amount of water which can be withdrawn from the groundwater reservoir and used economically each year for an indefinite period of time. The perennial yield of Kobeh Valley has been estimated to be 16,000 ac-ft/yr, together with an agricultural demand of 3,240 ac-ft/yr, would amount to an annual withdrawal of 10,870 ac-ft/yr which is well within Kobeh Valley's perennial yield. This yield would not result in a regional impact on the valley groundwater system over the project life.

The project would have a local effect on water table elevations in the vicinity of the well field. The Kobeh A well field is in the upper north-central portion of the valley, 7.5 miles west-southwest of the mine site. Based on an analysis of drawdown effects of this well field (Hydro-Search, Inc., 1983), existing wells that may be affected by pumping over the project

lifetime have been determined (refer to Sec. 2.1.3 Table 2-8). Water levels in wells within a six-mile radius of well field A (Alternate 3-C) would probably experience a gradual decline over the project lifetime. Actual drawdown in the aquifer during the project life at well field A would depend on aquifer recharge, aquifer hydraulic coefficients and the well field location and configuration. Distance to the nearest existing wells would depend on the final well field location but would probably be two to three miles.

Based on assumed aquifer coefficients of transmissivity (250,000 gpd/ft) and a storativity of 0.01 (Hydro-Search, Inc., 1982), drawdown adjacent to the Kobeh A well field would probably not exceed 100 feet during the project life and at six miles, drawdown would probably be less than 50 feet.

The Kobeh Test Site and Kobeh C well fields (Proposed action and Alternate 3-B) are located in Kobeh Valley on alluvium south of Mt. Hope about eleven and nine miles southwest of the mine site respectively. The actual location of the well fields would depend upon the geological contact between the Western and Eastern Assemblage rocks.

The influence of either well field on nearby water levels would be similar to but less than that described for Kobeh A. Six existing wells potentially could experience a decline in water levels as the result of pumping at the Kobeh C well field (refer to Sec. 2.1.3 Table 2-8). Predicted drawdown peripheral to the Kobeh Test Site and Kobeh A well fields are significantly less than at the Kobeh A site due to a laterally more extensive aquifer.

The five-year pit plan has been revised since completion of the Hydro-Search study. Based on the most recent mine plan provided by EXXON (October, 1982), at the end of the five years the pit bottom would be at a 6,400 ft elevation or below the projected water table. Consequently, hydrologic investigation and formulation of de-watering plans cannot be deferred, but must be defined early in the life of the mine.

Based on data, it was estimated that inflow to the pit after 14 years of operation could range from 1.5 to 3.8 M^3/M (400 to 1,000 gpm) with a best estimate of about 2.6 M^3/M (700 gpm). Approximately 1.2 to 2.7 M^3/M (325 to

722 gpm) of the total flow would derive from lateral inflow (depending on transmissibity of the wall rocks) and 0.1 to 0.9 M^3/M (25 to 249 gpm) from vertical flow through the bottom of the pit from the Eastern Assemblage rocks at depth.

Inflow to the pit after 20 years was estimated at 2.6 to 14 M^3/M (700 to 3,700 gpm) with a best estimate of about 8.3 M^3/M (2,200 gpm). Approximately 1.9 to 8.2 M^3/M (514 to 2,160 gpm) of the total flow would derive from lateral inflow and 0.6 to 5.8 M^3/M (152 to 1,522 gpm) from vertical flow through the pit bottom. Data concerning the possible direct interconnection of the Eastern Assemblage carbonates (at depth) with the wall rocks of the proposed pit via fracturing or faulting were not available. Such data would allow for the evaluation of whether the regional aquifer (Eastern Assemblage) would act as a major (direct connection) or minor source replenishment for water pumped from the pit; without such data the broad range of inflow values is necessary.

Existing wells that may be affected by pumping over the project lifetime have been determined (refer to Table 2-8). Based on an assumed aquifer transmissivity coefficient of 250,000 gpd/ft and a storativity of 0.01 (Hydro-Search, Inc., 1982), drawdown adjacent to the well field probably would not exceed 35 ft during the project life, and at six miles, drawdown probably would be less than 15 to 18 feet. One of the wells listed in Table 3-8 (20/52-18ab) may be affected by the drawdown and may then have to be deepened if it were to remain productive.

Principal springs in Kobeh Valley generally occur in the vicinity of Bean Flat (T19 and 20N., R49E), the Bartime Ranch (T19N., R50E) and the Hay Ranch (T20N., R52E) (Rush and Everett, 1964). The proposed well field is located approximately 15 miles from the Bean Flat and Bartime Ranch area and about 6 miles from the Hay Ranch. Spring flows at the Hay Ranch occur on the south side of the slough and playa. As such, well pumping at the well field would have no effect on the springs.

The impacts of drawdown, limited to a production decrease at a single well and no adverse effects to springs in the area, have been determined insignificant.

Table 3-8 Summary of Existing Wells That May be Impacted by Groundwater Withdrawal

Well No.	Depth of Wells (feet)	Source of Water	Elevation at Well (feet)	Water Level Below Land Surface Datum (feet)	Elevation of Water Level (feet)	Date of Measurement	Use of Water
Existing Wells That May be Affected by Well Field Kobeh "A"							
1 (22/51-19C) Roberts Cr. Ranch	350	Alluvium	6491	142	6349	10/58	Irrigation
2 (22/50-31C) BLM	289	?	6410	239	6171	4/70	?
3 (21/50-17bd) BLM	124	Alluvium	6203	50	6153	4/74	Stock Watering
4 (21/50-12cd) BLM	280	Alluvium	6269	228	6041	4/70	Stock Watering
Wells that May be Affected by Well Field Kobeh "C"							
6 (20/52-20ab) A.C. Florio	120	Alluvium	6012	16	5996	5/51	Irrigation
7 (20/52-18ab) Hay Ranch	25	Alluvium	6014	6.3	6008	11/18/53	Stock Watering
8 (20/52-18CA) Lucky C Cattle Co	85	Alluvium	6005	5	6000	9/66	Irrigation
9 (20/52-17bd) Hay Ranch	90	Alluvium	6020	17.8	6002	11/18/53	Irrigation
10 (20/52-17CA) Lucky C Cattle Co	85	Alluvium	6005	5	6000	9/66	Irrigation
11 (20/51-13AC) Lucky C Cattle Co	95	Alluvium	6008	5	6003	12/65	Irrigation

CHAPTER 4.0
LIST OF PREPARERS

4.1 Bureau of Land Management

TERESA McPARLAND, Area Geologist

B.A. Geology, Stephens College, MO.

Experience includes four years experience with Bureau of Land Management; coordinator, writer-editor; geology review.

WILLIAM M. O'BRIEN, JR., Visual Analyst

B.S. in Landscape Architecture, Pennsylvania State University
Post-Graduate Studies in Civil Mine Engineering, West Virginia University

Mt. Hope Project: Responsible for visual response evaluation and impact assessment. Prepared technical report and impact section discussion for EIS documentation.

Professional experience includes review and evaluation of mining and reclamation plans, development of mitigative programs, project engineering and plans design. Has assisted in management and preparation of numerous environmental impact statements and EISs; analysis of overall environmental impacts, recreational, planning, esthetics and inventory of natural systems.

Experience has emphasized energy development projects, particularly mine operations, throughout the United States.

NEIL D. TALBOT, Area Manager.

B.S. Range Management, Utah State University, Logan.

Experience includes twenty years with Bureau of Land Management; team leader.

ED TILSEY, Nevada State Environmental Specialist.

B.S. Wildlife, University of Montana.

Experience includes nine years in environmental protection with Bureau of Land Management; overall document review.

CRAIG L. WESTENBURG, District Hydrologist.

B.S. Watershed Management, University of Arizona, Tucson.

Experience includes three and one-half years experience with Bureau of Land Management; groundwater resources review.

4.2 Consultants

ROBERT C. WYATT, Project Manager

B.S. in Biology, University of Miami
Post Graduate Study, Biology, University of Miami

Mt. Hope Project: Responsible for coordination of environmental discipline impact analyses (except cultural resources) and direction of the third party EIS scientific team; technical and regulatory (NEPA) oversight and management of EIS documentation; and liaison and coordination with the Bureau of Land Management (BLM) and EXXON.

Experience includes management and technical analyses of environmental impact studies involving surface and underground mines, nuclear and coal-fire electrical generating plants, petrochemical and mineral process facilities, and hazardous waste/nuclear disposal site regulatory analysis. Professional experience involving activity in 23 states, Mexico and Puerto Rico has included the technical critique and environmental discipline analysis of hydrology, air quality, chemical and mine engineering, terrestrial and aquatic biology, socioeconomics, land use, pollutant toxicity and regulatory compliance.

MAXWELL K. BOTZ, Senior Hydrologist

B.S. in Geological Engineering, University of Nevada
M.S. in Geological Engineering, University of California, Berkeley
Ph.D in Hydrology, University of Arizona (dissertation not completed)
Professional Engineer, States of Colorado, Wyoming, Utah

Mt. Hope Project: Responsible as senior scientist for design and supervision of geohydrologic analyses, impact assessments and technical report preparation pertinent to EIS documentation.

Professional experience in excess of twenty years includes project direction for major mining, reclamation and water resources investigations. Emphasizing hard rock and coal mining, experience has included engineering design and construction of a hazardous waste site, development of water surplus, mineral processing treatment research, and groundwater pollution investigations. Employment history has included responsibility as Head of Technical Investigation Section, Water Quality Bureau, Montana Department of Health and Environmental Sciences.

CHUCK DALBY, Geologist/Hydrologist

B.A. in Geology, University of Montana
M.S. in Geology, University of Montana

Mt. Hope Project: Responsible for data compilation and analytical assistance relative to hydraulic assessment of tailings pond effluent migration and area hydrology.

Professional experience emphasizes the design and performance of hydrologic and geologic studies to determine impacts of energy facility siting. Employment has included experience with the Montana Department of Natural Resources and Conservation as a geologist/hydrologist responsible for coordination of inter-agency research efforts and preparation of environmental study plans.

RANDALL K. BUSH, Geologist/Data Analyst

B.S. in Geology, University of Houston

Mt. Hope Project: Assisted in the preparation and data abstraction required for EIS technical reporting. Coordinated EIS documentation relevant to mapping and quality assurance.

Professional experience includes technical writing and regulatory compliance documentation for numerous coal and mineral mines; technical critique of topographic and geologic data and support documentation; and land use analysis (physical environmental factors relevant to engineering planning).

JOHN V. A. SHARP, Project Manager

Ph.D. in Geology, University of Colorado
A.M. in Geology, Columbia University
A.B. in Geology, Haverford College

Mt. Hope Project: Responsible for project coordination and overall quality assurance. Principal water rights advisor.

Experience includes 30 years of professional and supervisory experience in planning and performance of consulting projects in the areas of ground and surface water hydrology, ground water resource development and water rights, operational mining hydrology, chemical quality of water, waste water disposal and monitoring, seepage, artificial recharge, geothermal development, geophysical exploration and environmental impacts.

RICHARD J. BERGER, Senior Hydrologist

M.S. in Geology, Michigan Technological University
B.S. in Geology, University of Wisconsin, Oshkosh

Mt. Hope Project: Responsible for project management and coordination of field engineering, analysis well-drilling and reporting. Water rights advisor.

Experience includes 13 years in the planning and performance of projects in the areas of ground water supply exploration and development, waste water disposal and monitoring, and environmental assessments associated with mining operations, solid waste disposal and energy development.

FORREST L. FOX, Hydrologist

M.S. in Hydrology, University of Nevada, Reno
B.S. in Geology, University of Nevada, Reno

Mt. Hope Project: Plan and conduct field and office investigations in well design, construction and completion. Water quality sampling and analysis.

Experience includes 8 years in the design and construction of ground water test and observation wells, performance and analysis or aquifer pumping tests, water chemistry/quality studies.

RODNEY A. FRICKE, Hydrologist

M.S. in Geology, University of Nevada, Reno
B.S. in Geology, Southern Illinois University

Mt. Hope Project: Performance of pumping tests and analysis, water quality monitoring.

Experience includes 7 years in the conducting of ground water investigations including drilling and well construction programs, water quality and geochemical analysis and ground water resource evaluation.

FORREST W. GIFFORD, Manager Mine/Mill Waste Disposal

B.S. in Civil Engineering, Kansas University
Registered Civil Engineer - California

Mt. Hope Project: Responsible for coordination and direction of the tailings site selection and conceptual design development study.

Mr. Gifford is in charge of engineering services and mill/mine waste disposal. These services have included investigations and design of new disposal facilities for uranium, silver, copper, and phosphate tailings facility and have involved various types of both earthfill and tailings embankments. He also has extensive experience in foundation and engineering analysis of existing mill waste embankments and tailings ponds.

ANTONIO S. BUANGAN, Manager Engineering Geology

B.S. in Mining Engineering, Mapua Institute of Technology, Phillipines
Post Graduate Study: Geology, Stanford University
Registered Geologist and Certified Engineering Geologist - California

Mt. Hope Project: Responsible for the direction of all geologic activities associated with the tailings site selection and conceptual designs study.

Professional experience includes conducting engineering and geologic studies to determine foundation conditions, availability of construction materials, seismicity and groundwater conditions for numerous civil

engineering projects, including dams, tailings dams, reservoirs, pipelines, roads, and various types of buildings, and land develpment. Broad experience in evaluating and developing mitigation measures for geologic hazards such as landslides and faulting related to hillside and highway projects, schools, and hospital sites.

DENNIS BURANEK, Principal Engineer

B.S. in Civil Engineering, San Jose State
M.S. in Civil Engineering, San Jose Sate
Registered Civil Engineer - California

Mt. Hope Project: Responsible as the principal engineer in evaluating engineering characteristics in relation to site development for tailings site selection, as well as engineer responsible for developing the recommended conceptual design of the tailings facilities.

Mr. Buranek has experience in design work for several uranium, silver, gold, and phosphate tailings disposal projects. He has served as project engineer for design of a 180 ft. high tailings retention dam in Colorado, a large uranium tailings disposal facility in New Mexico, and he has designed four other earth dams (maximum height 155 ft.) for the uranium milling operation in New Mexico. This work has included direction of site selection in alternative studies and preparation of preliminary cost estimates, design reports, and construction plans and specifications, as well as permitting assistance with regulatory agencies.

RICHARD C. HOUSTON, Project Manger, Mountain States Engineering

Engineer of Mines Degree, Colorado School of Mines
M.B.A., University of Arizona
Registered Engineer - Colorado and Arizona

Mt. Hope Project: Responsible for direction of tailings distribution system development and water reclamation pipe and pump system evaluation.

Responsible as project engineer for numerous projects located in the Southwest. Responsible for design and construction of surface facilities for uranium mines, including hoisting plant and shaft dewatering systems. Supervised construction of all surface facilities associated with developing a 30,000 TPD molybdenum mine. Project manager for platinum paladium mine feasibility study.

CHARLES J. BENNETT, Environmental Specialist, Normandeau Associates, Inc.

B.A. in Geography, Middlebury College
M.A. in Geography, Syracuse University
Ph.D. in Geography, Syracuse University

Mt. Hope Project: Responsible for coordination and environmental assessments relevant to site selection process for a tailings facility.

Responsible for: baseline studies in mining reclamation plans for surface mines, Gillette, Wyoming, environmental and regulatory overview of an East Texas lignite mine; and a socio and economic land use baseline study for other East Texas mining prospect. Supervisor of Social Sciences, including supervision of Social Science components, including and EIS and a generating station and an alternate site in Kentucky.

ROBERT K. KENNEDY, Plant Ecologist, Normandeau Associates, Inc.

B.S. in Botany and Biology, South Dakota University
M.S. in Plant Ecology/Soils, Iowa State University
Ph.D. in Plant Ecology/Geography, University of Oklahoma

Mt. Hope Project: Responsible as a senior scientist for providing environmental assessments of alternative tailings sites during the site selection process for a tailings facility.

Professional experience includes project direction staffing and business development related to energy development projects in the west, preparation of environmental impact statements covering coal mine development of two electric generating units, and a 500 kV transmission line corridor in Montana. Also assumed technical direction of plant ecology studies, including field and laboratory sampling and analysis interpretation of vegetation data and report preparation. Designed and directed and environmental assessment study of cooling tower salts on vegetation and soils in a 12,000 acre area of Southwest Indiana.

4.3 EXXON Minerals Company (Tailings Effluent Seepage Character and Quality)

WALTER R. DAVIES, Minerals Processing Engineering

Higher National Certificate (Chemical Engineering)
Birkenhead Technical College, U.K.

Mt. Hope Project: Responsible for processing engineering development of molybdenite process facilities.

Experience includes process engineering design and project engineering of major copper and uranium processing facilities and the supervision of primary copper production facilities. For several years managed laboratory and centralized pilot plant facilities for large, integrated, primary metals producer.

CHARLES E. DOWNS, Ph.D., Mine Engineering Division

Ph.D. Water Resources Systems Management, Engineering Planning Program, Stanford University. M.S. Water Resources Engineering, Civil Engineering, Stanford University. B.S. Hydrology, University of Arizona.

Mt. Hope Project: Responsible technical design of water engineering aspects of project including in-house and contracted hydrologic studies, flow modeling, well drilling, water supply development, water rights and monitoring well systems.

Experience includes design, implementation and management of numerous multidisciplinary water/energy resource development projects: e.g. hydrologic safety and monitoring programs for nuclear power plants, uranium tailings ponds, transmission corridors, flood control and agricultural/irrigation projects.

H. PAUL ESTEY, Environmental and Regulatory Affairs

B.S. Civil Engineering, Washington State University
M.S. Sanitary Engineering, Washington State University

Mt. Hope Project: Established site reclamation requirements; assisted in establishing landfill requirements; assisted in developing mitigating measures and monitoring programs; assisted in developing pre-operational groundwater monitoring program.

Experience includes licensing and compliance programs for major nuclear fuel fabrication plants at three sites; also responsible for all environmental issues and programs at those sites. Has worked directly with U.S. Federal government, and the Federal Republic of West Germany. Participated in writing EIRs for four nuclear fuel fabrication plants, one nuclear fuel reprocessing plant, and two uranium enrichment (one laser and one centrifuge) plants.

MOISES J. GARCIA, Engineering Advisor

B.S. Mining Engineering, New Mexico Institute of Mining and Technology

Mt. Hope Project: Project core team member responsible for coordinating feasibility work in mine design, hydrology, topographic mapping, and bulk sampling.

Experience includes twenty four years in designing, operating, and managing open pit mines. Several years in reclaiming open pit mine areas.

KIT R. KRICKENBERGER, Environmental and Regulatory Affairs

B.S. Geology/Chemistry, Bowling Green State University
Ph.D. Marine Geochemistry, University of Maryland

Experience includes management of large multi-disciplinary environmental consulting group preparation of many site-specific, regulatory and programmatic NEPA compliance documents for several federal agencies.

EDWIN S. ROUSSEAU, Engineering Advisor

B.S. Metallurgical Engineering, Michigan Technology University
B.S. Engineering Administration, Michigan Technology University
M.S. Metallurgical Engineering, University of Minnesota

Mt. Hope Project: Responsible for process design of process plant and tailing disposal system including descriptions of emissions and effluents and process wastes.

Experience includes testing, project manager and operation of large copper porphyry and uranium hydrometallurgical plants and preparation of environmental impact reports and license applications for uranium plant construction/modifications.

JOHN L. SHAFER, Mineral Process Engineer

B.S. Chemistry, Alleghany College
Ph.D. Inorganic Chemistry, University of California, Berkeley

Mt. Hope Project: Assisted in prediction of tailing water chemistry, water balances across mill - tailing complex, and tailings site selection and conceptual design.

Experience includes providing hydrogeochemical technical support for other developmental and operational projects; massive sulfide, copper/molybdenum, and uranium in situ.

JOHN F. WALLACE, Mine Engineering Division

B.S. Civil Engineering, S.U.N.Y. at Buffalo
MSCE Geotechnical Engineering, West Virginia University

Mt. Hope Project: Responsible for direction of tailings site selection and conceptual site development studies, seismic hazard assessments.

Experience includes execution and management of tailings facility planning and site development studies; geotechnical evaluations for numerous residential, commercial and industrial facilities; resident engineering for several large earthwork construction projects; and specialty consulting.

KAY KAY WONG, Communication and Computer Science Department

B.S. Physics, Seattle University
M.A. Physics, Columbia University

Mt. Hope Project: Responsible for computer graphics in three-dimensional visual display of mining area. Perform finite element analysis in rock mechanics and hydrology.

Experience includes developing a graphics system for satellite data at NASA.

CHAPTER 5.0
HYDROLOGY GLOSSARY

Alluvial fan. A fan-shaped deposit of sand, gravel and fine material dropped by a stream where its gradient lessens abruptly. Usually found at the base of highland terrain in arid regions.

Andesitic. Pertaining to andesite. A volcanic rock composed essentially of andesine and one or more mafic constituents. Pyroxene, hornblende, or biotite or all three in various proportions may constitute the mafic constituents.

Aquiclude. A formation which stores but does not transmit apprecialbe amounts of ground water (Davis and DeWiest, 1966). May act as a confining layer to a confined aquifer.

Aquifer. A formation, group of formations, or part of a formation which contain sufficient water-saturated permeable material to yield useful quantities of water to wells and springs (USGS, 1972).

Basal unit. Of, pertaining to, located at, or forming a base. The bottom member of a formation.

Basalt. A hard, dense, dark volcanic rock composed chiefly of plagioclase, augite and magnetite and often having a glassy appearance.

Breccia. A fragmental rock whose components are coarse angular fragments and therefore, as distinguished from conglomerates, are not waterworn. There are sedimentary breccias, friction or fault breccias, talus breccias and eruptive breccias. (Kemp)

Caldera. A large basin-shaped volcanic depression, more or less circular in form, the diameter of which is many times greater than that of the included volcanic vent or vents. (After Williams, H., Univ. Calif. Dept. Geol. Sci. Bull., vol. 25, pp. 242-246, 1941)

Cambrian. The oldest of the systems into which the Paleozoic stratified rocks are divided; also the corresponding geologic period.

Carbonate. A salt or ester of carbonic acid; a rock containing the radical CO_3, such as limestone or dolomite.

Chert. Sedimentary rock composed of exceedingly fine-grained quartz and opal.

Clastic. 1. In petrology, a textural term applied to rocks composed of fragmental material derived from pre-existing rocks or from the dispersed consolidation products of magmas or lavas. (Holmes, A., p. 60, 1920)
2. A clastic rock is one composed principally of detritus transported mechanically into its place of deposition. It may consist of material that was originally chemically or biogenetically deposited within the same basin, provided it was moved as particles before its final deposition. The commonest clastics are sandstones and shales as distinct from limestones and anhydrites. However, limestones formed from particles derived from pre-existing limes are clastic. (AAPG, 1949)

Claystone. Applicable to indurated clay in the same sense as sandstone is applicable to indurated or cemented sand. Rocks in which much clay is present or which are largely composed of clay sometimes bound together by iron carbonate. (Grabau, Textbook of Geol., p. 580, 1920)

Conglomerate = Puddingstone. 1. Rounded water-worn fragments of rock or pebbles, cemented together by another mineral substance, which may be of a siliceous or argillaceous nature. This is locally termed "pudding stone." (Roberts, G., Etymol. and Explan. Dict. Geol., p. 34, 1839) 2. A cemented clastic rock containing rounded fragments corresponding in their grade sizes to gravel or pebbles. Monogenetic and polygenetic types are recognized, according to the uniformity or variability of the composition and source of the pebbles. (Holmes, 1928)

Contact. 1. The place or surface where two different kinds of rocks come together. Although used for sedimentary rocks, as the contact between a limestone and sandstone, it is yet more especially employed as between igneous intrusions and their walls. The word is of wide use in western mining regions on account of the frequent occurrence of ore bodies along contacts. (Kemp)

Contact metamorphism. Metamorphism genetically related to the instrusion or extrusion of magmas and taking place in rocks at or near their contact with a body of igneous rock.

Country rock. A general term applied to the rocks invaded by and surrounding an igneous intrusion. (After Holmes, A., 1920)

Culvert. A drain crossing under a road or embankment.

Detrital = Clastic, q.v. = Allogenic, q.v. Said of minerals occurring in sedimentary rocks, which were derived from preexisting igneous, sedimentary or metamorphic rocks. (After Twenhofel, Prin. Sed., p. 284, 1950)

Devonian. In the ordinarily accepted classification, the fourth in order of age of the periods comprised in the Paleozoic era, following the Silurian and succeeded by the Mississippian. Also the system of strata deposited at that time. (La Forge) Sometimes called the Age of Fishes.

Dolomite. Sedimentary rock or mineral composed primarily of the mineral dolomite [Ca Mg $(CO_3)_2$].

Drainage basin. A part of the surface of the lithosphere that is occupied by a drainage system or contributes surface water to that system.

Ephemeral. Lasting for a brief time, short-lived.

Erosion. The group of processes whereby earthy or rock material is loosened or dissolved and removed from any part of the earth's surface. It includes the processes of weathering, solution, corrosion, and transportation. The mechanical wear and transportation are effected by running water, waves, moving ice, or winds, which use rock fragments to pound or grind other rocks to powder or sand. (Ransome, F. L., USGS Prof. Paper 115, p. 182, 1919)

Eugeosyncline. A long, narrow geosyncline in which volcanic rocks are abundant. (Kay, 1951)

Evapotranspiration. A term embracing the portion of the precipitation returned to the air through direct evaporation or by transpiration of vegetation, no attempt being made to distinguish between the two. (Langbein, W. B., Trans. Amer. Geophys. Un., vol. 23, pt. 2, p. 610, 1942)

Extrusive. A term applied to those igneous rocks derived from magmas or magmatic materials poured out or ejected at the earth's surface. Synonymous with effusive rocks, volcanic rocks.

Fault. A fracture in rock where movement of one side with respect to the other has occurred (Reid, 1913). The movement or displacement may be a few inches to several miles.

Flood plain. Nearly level land, consisting of stream sediments, that borders a stream and is subject to flooding unless protected artificially.

Formation. "In geology, any assemblage of rocks which have some character in common, whether of origin, age, or composition." (Lyell, Manual of Geol. 6th Ed., p. 2, 1858)

Geosyncline. A large elongate basin within which great thicknesses of sedimentary and volcanic rocks are acumulating due to a regional extent of subsidence over a long time. Geosynclines are prevalently linear, but non-linear depressions can have properties that are essentially geosynclinal. (After Kay, p. 4, 1951; furst used by J. D. Dana in 1873).

Hardpans. A hard impervious layer, composed chiefly of clay, cemented by relatively insoluable materials, does not become plastic when mixed with water, and definitely limits the downward movement of water and roots.

Hornfels. A fine-grained, non-schistose metamorphic rock resulting from contact metamorphism.

Host Rock. The wall rock of an ore deposit that has undergone a change in mineral characteristics due to outside influence.

Hydraulic. Of or pertaining to fluids in motion; conveying, or acting by water; operated or moved by means of water.

Hydraulic conductivity. Ability to transmit in unit time a unit volume of ground water at the prevailing viscosity through a cross section of unit area, measured at right angles to the direction of flow, under a hydraulic gradient of unit change in head through unit length of flow (Lohman, 1972) (gpd/ft^2, m/d).

Hydraulic gradient. The change in static head per unit of distance in a given direction (USGS, 1972).

Hydraulic potential. The level to which water will rise in a cased well.

Hydrogeological. Pertaining to hydrogeology - Hydrology.

Hydrograph. A graph showing stage, flow, velocity, or other property of water with respect to time.

Hydrologic soil group. A group of soil series with similar hydrologic characteristics. The Soil Conservation Service has grouped major soils of the United States into four hydrologic soil groups. These groups are based on intake of water at the end of long-duration storms after prior wetting and opportunity for swelling, with consideration of the protective effects of vegetation (Archer, 1980).

Hydrology. The science of the distribution and phenomena of water on the earth's surface.

Igneous rock. Rock that has been formed by the cooling of molten mineral material. Examples: Granite, syenite, diorite, and gabbro.

Incised. Cut into; carved; deeply notched.

Interstratified. Inter bedded; strata laid between or alternating with others.

Intrusive. Magma or plastic solid which penetrates in or between older rock and solidifies before reaching the surface.

Lacustrine. Produced by or belonging to a lake environment. (Emmons, Ebeneyer, Man. of Geol., 1860)

Limestone. Sedimentary rock composed predominantly of calcite; $CaCO_3$.

Lithologic units. A rock unit. A rock body distinctive enough to be delineated from adjacent rock bodies along surfaces called contacts.

Minimum retention rate. The minimum constant soil infiltration rate after saturation, estimated for each hydrologic soil group.

Miogeosyncline. A long, narrow geosyncline in which volcanic rocks are rare or absent. (Kay, 1951)

Mississippian. Formerly the lower of two epochs into which Carboniferous was subdivided. Recently, the Am. Comm. Strat. Nomenclature recommended advancement to period rank, and that now accepted by U.S. Geol. Surv. In America, Mississippian is fifth of seven periods in the Paleozoic Era. Also the system of rocks found during the period.

Normal fault. A fault at which the hanging wall has been depressed, relative to the footwall. (Lindgren, p. 140, 1933)

Olivine. A mineral silicate of iron and magnesium, principally Fe_2, Si O_4 and Mg_2 Si O_4, found in igneous and metamorphic rocks.

Ordovician. The second of the periods comprised in the Paleozoic era, in the geological classification now generally used. Also the system

of strata deposited during that period. (La Forge) In older literature, it was called "Lower Silurian."

Orogeney. The process of formation of mountain ranges by folding, faulting and thrusting. (After Upham, W., four. Geol. 2, p. 383, 1894)

Orographic rainfall. Rainfall resulting when moist air is forced to rise by mountain ranges lying athwart the path of the wind.

Outcrop. A portion of bedrock or other stratum protruding through the soil level.

Paleozoic. One of the eras of geologic time that, between the Late Precambrian and Mexozoic eras, comprises the Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian systems. The beginning of the Paleozoic was formerly supposed to mark the appearance of life on the earth, but that is now known to be incorrect. Also the group of rocks deposited during the Paleozoic era.

Pediment. 1. Steep rock slopes having roughly triangular shapes resembling architectural pediments. (Dutton, Tertiary History of the Grand Canyon, Atlas Sheet 5, 1882) 2. Gently sloping plains eroded at the foot of steep slopes or cliffs. (McGee, W. J., GSA Bull. 8, p. 92, 1897)

Perennial yield. The maximum amount of water of useable chemical quality that can be withdrawn from a ground-water reservoir and used economically each year for an indefinite period of time. The perrenial yield is limited ultimately to the amount of natural discharge that can be economically salvaged for beneficial use. (Rush and Everett, 1964) (usually given in AF/yr, hm^3/yr).

Permian. Formerly the last of the three epochs in the Carboniferous period. In recent years advanced to period rank by U.S. Geol. Surv. Now considered by Am. Comm. on Strat. Nomenclature as last of seven periods in Paleozoic Era. Also the system of rocks formed during the period.

Permeability. The capacity of rock for transmitting a fluid. Also, the ease with which gases, liquids or plant roots penetrate or pass through a bulk mass of soil or a soil layer.

Phreatophyte. A plant that habitually obtains its required water supply from the zone of saturation, either directly or through the capillary fringe. (Meinzer, USGS WSP 494, p. 55, 1923)

Playa. The shallow central basin of a desert plain or valley in which water gathers after a rain and is evaporated. (U.S. Geol. Surv., Bull. 613, p. 184)

Pleistocene. The earlier of the two epochs comprised in the Quaternary period, in the classification generally used. Also called Glacial epoch and formerly called Ice age, Post-Pliocene, and Post-Tertiary. Also the series of sediments deposited during that epoch, including both glacial deposits and ordinary sediments. Some geologists formerly used Pleistocene as synonymous with Quaternary and included in it all post-Tertiary time and deposits. (La Forge)

Potentiometric. Pertaining to a potentiometer. An instrument for measuring an unknown voltage or potential difference by comparison to a standard voltage.

Precipitation. The discharge of water, in liquid or solid state, out of the atmosphere, generally upon a land or water surface.

Prototype production well. A well constructed on the basis of compiled hydrogeological data for the purposes of aquifer performance analysis. Normally becomes a production well upon completion of aquifer testing and is the basis for design of other wells in a given well field.

Pumping water level. The depth to water in a well determined by adding the drawdown in the well due to pumping to the static water level. Pump intakes should be set below this depth (ft, m).

Quartzite. 1. A granulose metamorphic rock consisting essentially of quartz. 2. Sandstone cemented by silica which has grown in optical continuity around each fragment. (After Homes' Nomenclature of Petrology, p. 194, 1950) See: Arkose quartzite, Arkosite, Gneissic quartzite, Granulite, Graywacke quartzite, Slaty quartzite.

Quartz latite. The extrusive equivalent of a quartz monzonite. The principal minerals are quartz, sanidine, biotite, sodic plagioclase and often hornblende usually occurring as phenocrysts in a groundmass of potash feldspar and quartz (or tridymite-cristobalite), or glass. Accessory minerals are magnetite, apatite and zircon. With an increase in silica and alkalies the rock passes into a rhyolite and with a decrease in these constituents it passes into a dacite.

Recent. The later of the two geologic epochs comprised in the Quaternary period, in the classification generally used; same as Holocene. Also the deposits formed during that epoch. (The Holocene, or Recent, comprises all geologic time and deposits from the close of the Pleistocene or Glacial epoch until and including the present.) (La Forge)

Recurrence probability. The probability that in any given time period, a runoff event of a given magnitude will be exceeded.

Rhyolite. The extrusive equivalent of a granite. The principal minerals being one or more of the silica minerals (e.g., quartz, alkali feldspar).

Runoff curve number. A value obtained from a graph of a family of curves which represents the relationship between rainfall and direct runoff for a given watershed.

Sandstone. Variously colored sedimentary rock composed predominantly of sandlike quartz grains cemented by lime, silica, or other materials.

Shale. 1. A laminated sediment, in which the constituent particles are predominantly of the clay grade. (Holmes, 1928) 2. Shale includes the indurated, laminated or fissile claystones and siltstones. The cleavage is that of bedding and such other secondary cleavage or fissility that is approximately parallel to bedding. The secondary cleavage has been

produced by the pressure of overlying sediments and plastic flow. (Twenhofel, W. H., Rept. Comm. Sed., p. 98, 1936-1937)

Shearing. The deformation or rocks by the cumulation of small lateral movements along innumerable parallel planes, resulting from pressure.

Silica. Silicon dioxide, SiO_2.

Siliceous. Of or pertaining to silica; containing silica, or partaking of its nature. (Webster) Containing abundant quartz. Also spelled Silicious.

Siltstone. A very fine-grained consolidated clastic rock composed predominantly of particles of silt grade. (AAPG, 1949)

Skarn. The term is generally reserved for rocks composed nearly entirely of lime-bearing silicates and derived from nearly pure limestones and dolomites into which large amounts of Si, Al, Fe, and Mg have been introduced.

Specific yield. The ratio of the volume of water which a rock or soil, after being saturated, will yield by gravity to the volume of rock or soil (USGS, 1972). Usually used to describe storage characteristics of unconfined aquifers (dimensionless).

Static water level. The depth at which water stands in a well when no water is being taken from the aquifer either by pumping or free flow (Johnson Division, UOP Inc., 1975) (ft, m).

Storage coefficient. The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head (Lohman, 1972). Usually used to describe storage characteristics of confined aquifers (dimensionless).

Subsidence. A sinking of a large part of the earth's crust. Movement in which there is no free side and surface material is displaced vertically downward with little or no horizontal component.

Tertiary. The earlier of the two geologic periods comprised in the Cenozoic era, in the classification generally used. Also the system of strata deposited during that period. (La Forge)

Thrusting. Pertaining to a thrust fault. A fault characterized by a low angle of inclination with reference to a horizontal plane and the dominant movement of the rocks above the fault surface being up the dip of the fault. The rocks above the fault appear to have been pushed or thrust over those below.

Transmissivity. The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient (USGS, 1972) (gpd/ft, m^2/d).

Tuff. A rock formed of compacted volcanic fragments, generally smaller than 4mm in diameter. (After Holmes, 1928)

Unconformable. Having the relation of unconformity to the underlying rocks; not succeeding the underlying strata in immediate order of age and in parallel position. (La Forge)

Uplift. Elevation of any extensive part of the earth's surface relatively to some other part; opposed to Subsidence.

Volcanic. Of, pertaining to, like, or characteristic of, a volcano; characterized by or composed of volcanoes, as a volcanic region, volcanic belt; produced, influenced, or changed by a volcano or by volcanic agencies; made of materials derived from volcanoes, as a volcanic cone. See Neptunic; Plutonic. (After Webster, 1948)

Watershed. A ridge of high land dividing two areas that are drained by different river systems. The region draining into a river, river system, or body of water.

CHAPTER 6.0
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APPENDIX 4-A

WELL RECORDS

APPENDIX A

WELL RECORDS

Records of selected wells in Kobeh, Diamond, and Garden/Pine Valleys are summarized in Table A-1. All wells are designated by a single numbering system which is referenced to the Mount Diablo base line and meridian established by the General Land Office (Eakin, 1962). The first number is the township north of the Mount Diablo base line. The second number, separated from the first by a slant line, is the range east of the Mount Diablo meridian. Separated from the second number by a dash is the third number which designates the section within the township. This is followed by two lower case letters. The first represents the quarter section, and the second designates the quarter-quarter section. The letters a, b, c, and d represent, respectively, the northeast, northwest, southwest, and southeast quarter and quarter-quarter sections. For example, 21/50-12cd represents a well located in the southeast quarter of the southwest quarter of Section 12, Township 21 North, Range 50 East.

Most of the information in Table A-1 for Kobeh Valley was obtained from well records obtained from the Nevada State Engineer's Office. In many cases these records are not complete. On some records no water level measurements are recorded, whereas on others, well locations are not complete enough to accurately locate the wells. For such cases the well records are not included in Table A-1 since they are of little value for the hydrologic investigation. As shown on Table A-1,

much of the available data is old. However, since Kobeh Valley has not been extensively developed, water levels probably have not changed drastically over the years. It is felt that the water level data listed in Table A-1 and shown on Plate III, represents a reasonable approximation of the existing conditions in Kobeh Valley.

Much of the well information initially obtained for Diamond Valley is also relatively old. Because of the extensive agricultural development in Diamond Valley, and the resultant decline in water levels during the past 15 to 20 years, correlation of water levels between wells made at varying points in time is difficult. The Nevada State Engineer's Office (Elko Branch) monitors a large number of wells in Diamond Valley on a yearly basis. These data were obtained and are listed in Table A-1 and plotted on Plate III. Only measurements made during Spring are used as they reflect water level conditions before the irrigation season begins. In this manner, a more reasonable approximation of static water level conditions in Diamond Valley is obtained. Unfortunately, the information obtained from the State Engineer's Office is limited to well locations and associated water level measurements only. It does not include data concerning geology and well completion. Wherever possible, this information was matched with more complete well records previously obtained.

The situation in Garden/Pine Valley is very similar to that in Kobeh Valley. Agricultural development is not as extensive as Diamond Valley

and, therefore, well information is limited. As in Kobeh Valley, some of the available records are incomplete. Even though most of the available data are old, and because ground-water withdrawal due to pumping is relatively minor, the data listed in Table A-1 and shown on Plate III probably presents a reasonable estimate of existing conditions in Garden/Pine Valley.

Table A-1. Records of Selected Wells in Kobeh, Diamond, and Garden/Pine Valleys.

Location	Owner or User	Depth of Well, feet (meters)	Geologic Source of Water	Elevation at[1] well, feet (meters)	Water Level Below Land Surface Datum, feet (meters)	Elevation of[2] Water Level, feet (meters)	Date of Measurement	Use of Water
Kobeh Valley								
18/51-10ba	Unknown	Unknown	Unknown	6230 (1900.2)	176.7 (53.9)	6053 (1846.2)	4/16/64	Stock watering
18/51-22db	Angelo Florio	135 (41.2)	Alluvium	6230 (1900.2)	58.8 (17.9)	6171 (1882.2)	4/16/64	Stock watering
19/49-18ca	Paul Conlan	90 (27.5)	Alluvium	6190 (1888.0)	23 (7.0)	6167 (1880.9)	9/1/59	Stock watering
19/49-30aa	Maurice Farr	223 (60.0)	Volcanics	6280 (1915.4)	90 (27.5)	6190 (1888.0)	5/64	Domestic; irrigation
19/50-30db	Eureka Ranch Company	157 (47.9)	Alluvium	6267 (1911.4)	35 (10.7)	6232 (1900.8)	8/67	Stock watering
20/49-9cd	Fred Etchegary and Son	250 (76.3)	Alluvium	6152 (1876.4)	6 (1.8)	6146 (1874.5)	9/51	Irrigation
20/49-17ab	(?) Smith	405 (123.5)	Alluvium	6197 (1890.1)	48 (14.6)	6149 (1875.5)	10/74	Stock watering
20/51-13ac	Lucky C Cattle Company	95 (29.0)	Alluvium	6008 (1832.4)	5 (1.5)	6003 (1830.9)	12/65	Irrigation

(1) Elevations estimated from USGS 15' quadrangle maps.

(2) Elevations in feet have been rounded.

(3) 5/79; measurement in spring of 1979.

(4) Harrill and Lamke (1968).

Table A-1. Records of Selected Wells in Kobeh, Diamond, and Garden/Pine Valleys (Cont'd).

Location	Owner or User	Depth of Well, feet (meters)	Geologic Source of Water	Elevation at(1) well, feet (meters)	Water Level Below Land Surface Datum, feet (meters)	Elevation of(2) Water Level, feet (meters)	Date of Measurement	Use of Water
Kobeh Valley (cont'd)								
20/52-17ca	Lucky C Cattle Company	85 (25.9)	Alluvium	6005 (1831.5)	5 (1.5)	6000 (1830.0)	9/66	Irrigation
20/52-17bd	Hay Ranch	90 (27.5)	Alluvium	6020 (1836.1)	17.8 (5.4)	6002 (1830.6	11/18/53	Irrigation
20/52-18ca	Lucky C Cattle	85 (25.9)	Alluvium	6005 (1831.5)	5 (1.5)	6000 (1830.0)	9/66	Irrigation
20/52-18ab	Hay Ranch	25 (7.6)	Alluvium	6014 (1834.3)	6.3 (1.9)	6008 (1832.4)	11/18/53	Stock watering
20/52-20ab	A. C. Florio	120 (36.6)	Alluvium	6012 (1833.7)	16 (4.9)	5996 (1838.8)	5/51	Irrigation
21/49-16c	Santa Fe Ranch	60 (18.3)	Alluvium	6230 (1900.2)	46.6 (14.2)	6183 (1885.8)	3/24/64	Stock watering
21/50-12cd	BLM	280 (85.4)	Alluvium	6269 (1912.1)	228 (69.5)	6041 (1842.5)	4/70	Stock watering
21/50-17bd	BLM	124 (37.8)	Alluvium	6203 (1891.9)	50 (15.3)	6153 (1876.7)	4/74	Stock watering
22/50-31c	BLM	289 (88.2)	Unknown	6410 (1955.1)	239 (72.9)	6171 (1882.2)	4/70	
22/51-19c	Roberts Creek Ranch	350 (106.8)	Alluvium	6491 (1979.8)	142 (43.3)	6349 (1936.5)	10/58	Irrigation
Diamond Valley								
20/53-1bd				5953 (1815.7)	113.8 (34.7)	5839 (1780.9)	5/79(3)	
20/53-10ca				5939 (1811.4)	98 (29.9)	5841 (1781.5)	5/79	
20/53-20bc				5953 (1815.7)	109.2 (33.3)	5844 (1782.4)	5/79	

Table A-1. Records of Selected Wells in Kobeh, Diamond, and Garden/Pine Valleys (Cont'd).

Location	Owner or User	Depth of Well, feet (meters)	Geologic Source of Water	Elevation at[1] well, feet (meters)	Water Level Below Land Surface Datum, feet (meters)	Elevation of[2] Water Level, feet (meters)	Date of Measurement	Use of Water
Diamond Valley (cont'd)								
20/53-22bc				6008 (1832.4)	164.1 (50.1)	5844 (1782.4)	5/79	
20/53-32bb				6032 (1839.8)	108.8 (33.2)	5923 (1806.5)	5/79	
21/53-1cd	Walter L. Plaskett	249 (76.0)	Alluvium	5887 (1795.8)	60.8 (18.5)	5826 (1776.9)	5/79	Irrigation
21/53-9cc	Howard Stearns	182 (55.51)	Alluvium	5888 (1795.8)	68.2 (20.8)	5820 (1775.1)	5/79	Irrigation
21/53-26db				5918 (1805.0)	82 (25.0)	5836 (1780.0)	5/79	
21/53-33ab				5918 (1805.0)	85.4 (26.1)	5833 (1779.1)	5/79	
21/54-4ad				5893 (1797.4)	63.4 (19.3)	5833 (1778.2)	5/79	
21 1/2/52-1bc[4]	Ruel Anderson	300 (91.5)	Alluvium	5831 (1778.8)	15.8 (4.8)	5815 (1773.6)	5/78	Irrigation
22/54-4cc				5840 (1781.2)	14 (4.3)	5826 (1776.9)	5/78	
22/54-8ad	O. C. Talbot	240 (73.2)	Alluvium	5842 (1781.8)	18.2 (5.6)	5824 (1776.3)	5/78	Irrigation
22/54-22cd				5859 (1787.0)	28.9 (8.8)	5830 (1778.2)	5/78	
22/54-32dd				5868 (1789.7)	44.7 (13.6)	5823 (1776.0)	5/79	
23/53-27bb[4]				5820 (1775.1)	13.3 (4.1)	5807 (1771.1)	5/79	
23/53-30dd[4]				5821 (1775.4)	14.90 (4.5)	5806 (1770.8)	5/79	

Table A-1. Records of Selected Wells in Kobeh, Diamond, and Garden/Pine Valleys (Cont'd).

Location	Owner or User	Depth of Well, feet (meters)	Geologic Source of Water	Elevation at[1] well, feet (meters)	Water Level Below Land Surface Datum, feet (meters)	Elevation of[2] Water Level, feet (meters)	Date of Measurement	Use of Water
Diamond Valley (cont'd)								
23/54-18db[4]				5800 (1769.0)	19.85 (6.1)	5780 (1762.9)	5/79	
23/54-30cd				5828 (1777.5)	12.6 (3.8)	5815 (1773.6)	5/78	
23/54-32bd	Ruel Anderson	300 (91.5)	Alluvium	5831 (1778.5)	15.8 (4.8)	5815 (1773.6)	5/78	Irrigation
Garden/Pine Valley								
23/52-19cc	Exxon	Unknown	Unknown	6520 (1988.6)	15 (4.6)	6505 (1984.0)	8/6/81	
25/49-7aa	E. Bauman	259.5 (79.2)	Alluvium	5794 (1764.2)	194 (59.2)	5600 (1708.0)	Unknown	Stock watering
25/50-28ca	S. Damele	126 (38.4)	Alluvium	5831 (1778.5)	7.64 (2.3)	5823 (1776.0)	10/20/60	Irrigation
25/51-3ac	Eureka Land and Livestock Co.	147 (44.8)	Alluvium	5750 (1753.8)	75 (22.9)	5675 (1730.9)	10/50	Stock watering
25/51-34aa	Eureka Land and Livestock Co.	64 (19.5)	Alluvium	5850 (1784.3)	25 (7.6)	5825 (1776.6)	7/58	Domestic
25/51-35bc	Eureka Land and Livestock Co.	170 (51.9)	Limestone(?)	5861 (1787.6)	27 (8.2)	5834 (1779.4)	8/58	Irrigation

APPENDIX 4-B

CONCEPTUAL WELL FIELD LAYOUTS

AND WELL FIELD SUMMARIES

APPENDIX B

CONCEPTUAL WELL FIELD LAYOUTS

AND WELL FIELD SUMMARIES

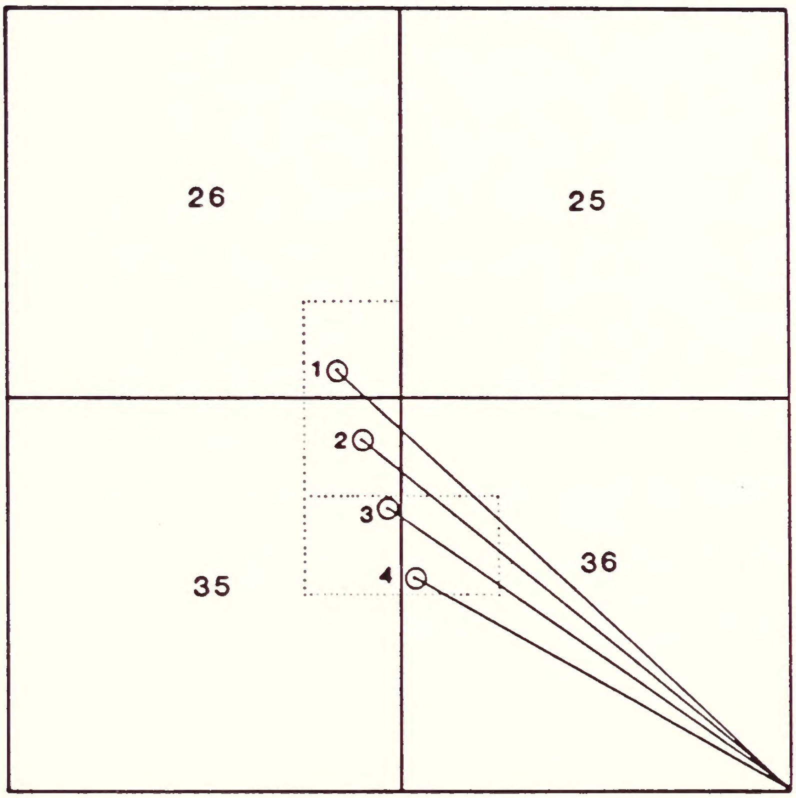
Figures B-1 through B-9 are conceptual well field layouts showing the location of each well site in a field with relation to 1) a 40-acre (16.2 ha) Township and Range plot, and 2) bearing and distance to a known section corner as identified on USGS 15-minute topographic maps. For Kobeh "B" and Diamond "B" well fields (Figures B-2 and B-5, respectively) the township and range sections are unsurveyed. As a result, the sections were projected to the well fields from the nearest surveyed area. Also for Kobeh "B" and Garden "A" well fields (Figures B-2 and B-7, respectively) 40-acre (16.2 ha) township and range plots could not be identified because of the irregularly shaped sections due to error in the original land survey.

A Well Field Summary follows each of the respective well field layouts. This is a summary of pertinent data on each well field as discussed in Section 6.2. The Well Field Summary form has been designed to be updated as more data become available and the design of the well fields progress. The reason that many spaces have been left blank is because these items are beyond the scope of the present study.

EXXON MINERALS COMPANY
KOBEH "A" WELL FIELD
EUREKA COUNTY, NEVADA

WELL SITE	BEARING	DISTANCE, feet	(m)
1	S47°20'E	8,342	(2544.3)
2	S50°45'E	7,471	(2278.7)
3	S55°15'E	6,653	(2029.2)
4	S60°45'E	5,834	(1779.4)

Bearing and distance is from well site to SE corner of Section 36.



T 22 N, R 50 E

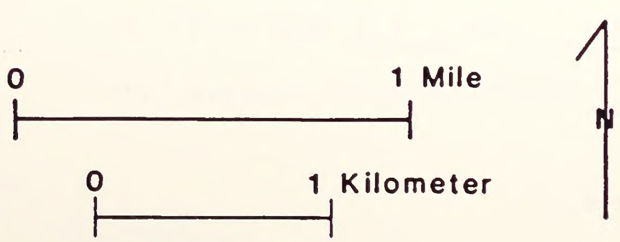


FIGURE B-1

WELL LOCATIONS

KOBEH "A" WELL FIELD

PROJECT 1298-82	REVISIONS
DATE March 1982	

Hydro-Search, Inc.
CONSULTING HYDROLOGISTS-GEOLOGISTS
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MT. HOPE PROJECT
PHASE I HYDROLOGY

Well Field Summary

Well Field Name Kobeh A

Priority Ranking

A. Well Field vs. Well Field 3

B. Within Basin 2

I. WATER RIGHTS ACQUISITION

A. Basin Name Kobeh Valley Designated-yes ____ no X

B. Points of Diversion (Well Locations)

1. SE 1/4, SE 1/4, Sec.26, T.22N., R.50E., M.D.B. & M.
2. NE 1/4, NE 1/4, Sec.35, T.22N., R.50E., M.D.B. & M.
3. SE 1/4, NE 1/4, Sec.35, T.22N., R.50E., M.D.B. & M.
4. SW 1/4, NW 1/4, Sec.36, T.22N., R.50E., M.D.B. & M.

C. Surface Elevation (above Mean Sea Level, USGS Datum)

1. 6435 ft. (1962.7 m) Est. from Topo Map X, Surveyed ____
2. 6415 ft. (1956.6 m) Est. from Topo Map X, Surveyed ____
3. 6400 ft. (1952.0 m) Est. from Topo Map X, Surveyed ____
4. 6385 ft. (1947.4 m) Est. from Topo Map X, Surveyed ____

D. Nearest Well or Permit

1. Permit Number 2732
2. Owner Roberts Creek Ranch
3. Status of Permit-Certificated Yes Permitted ____ Pending ____
4. Flow Rate 0.3 cfs (8.5 lps)
5. Distance from Well Field 2.0 mi (3.2 km), Northeast

E. Possible Problems with Water Rights Acquisition

Because Kobeh Valley is undesignated and this well field is located away from the relatively developed valley floor, few problems are anticipated.

II. HYDROGEOLOGIC DATA

A. Primary Aquifer

1. Geologic Unit Eastern Assemblage

2. Aquifer Materials Fractures and solution openings in limestones and dolomites

3. Saturated Thickness 500 ft (152.5 m)

4. Static Water Level

a. Depth below Surface 200 ft (61.0 m)

b. Elevation 6200 ft (1891.0m)

c. Estimated X, Measured ______ Date ______

5. Aquifer Parameters

a. Source, Pumping Test-yes ____ no X

Description ______

Other Source-yes X no ____

Explanation Estimated based on general hydraulic characteristics of Eastern Assemblage materials in other areas of

Nevada

b. Transmissivity (T) 250,000 gpd/ft (3100.0 m^2/d)

c. Hydraulic Conductivity (K) 500 gpd/ft^2 (20.4 m/d)

d. Storage Coefficient (S) 1×10^{-2}

7. Possible Boundaries Possible downfaulted block of Western Assemblage Vinini Formation may occur approximately 12,000 feet northeast of the well field trending in a northwest-southeast direction

B. Water Quality

1. Total Dissolved Solids (TDS) 200-500 mg/l
2. Electrical Conductivity (EC) ______ µmhos/cm @ 25°C
3. Temperature _____ °C
4. General Water Type Calcium-bicarbonate and sodium bicarbonate
5. Problem Constituents Manganese and iron may be high
6. Possible Treatment Necessary Not enough data available for evaluation

II. WELL FIELD DESIGN CRITERIA

A. General

1. Number of Wells

a. Primary __2__

b. Backup __2__

c. Total Number __4__

2. Capacity __2700__ gpm (__170.4__ lps)

3. Spacing __1000__ ft (__305.0__ m)

4. Total depth __700__ ft (__213.5__ m)

B. Well Design

1. Hole Diameter ____ in. (______ cm)

2. Drilling Method ____

____

____

____

3. Casing Requirements

a. Surface Casing

Type ____

Diameter ________ in. (________ cm)

Wall Thickness ________ in. (__________ cm)

Length ______ ft (_________ m)

Installation Depth from _____ ft (______ m) to _____ ft

(_____ m) below surface

Seal ____

____

____

b. Production Casing

Type ____

Diameter ________in. (________cm)

Wall Thickness _________in. (__________cm)

Length ______ft (_________m)

Installation ______________________________________

____

____

____

c. Screen

Type ____

Diameter _______in. (_______cm)

Size of Openings ______in. (_______cm)

Total Length ______ft (_______m)

Installation ______________________________________

____

____

____

4. Gravel Pack

a. Grain Size ______________________________________

____

b. Placement from _____ft (______m) to ______ft (_______m) below surface

c. Installation ______________________________________

____

____

____

d. Seal ____

____

____

____

C. Pump Design

1. Anticipated Pumping Water Level 280 ft (85.4 m) below Surface; 6120 ft (1866.6 m) Elevation

2. Head Loss due to Pump Column _____ft (______m)

3. Total Dynamic Head _____ft (_____m)

4. Pump Requirements

a. Type ____

b. Motor ______HP (_______Kw)

c. Number of Stages ______

d. Diameter of Pump Column _____in. (_____cm)

e. Pump Setting _____ft (______m) below Surface

_____ft (_____m) Elevation

D. Pipe Line Design

1. Lift from Well Field to Mill 465 ft (141.8 m)

2. Length of Pipeline

a. Tie Line Between Wells 3000 ft (915.0 m)

b. Well Field to Mill 39600 ft (12078.0 m) or

7.5 mi (12.1 km)

3. Diameter of Pipeline

a. Tie Line _____in. (______cm)

b. Transmission Line _____in. (______cm)

E. Estimated Costs for Wells and Pumps

1. Well Drilling and Completion

   $_________ per well x _____ wells = $_________Total for Well Field

2. Pumps (including installation)

   $_________ per installation x _____ wells = $_________ Total for Well Field

3. Total Estimate for Well Field $_________

EXXON MINERALS COMPANY
KOBEH "B" WELL FIELD
EUREKA COUNTY, NEVADA

WELL SITE	BEARING	DISTANCE, feet	(m)
1	S29°40'E	9,293	(2834.4)
2	S33°00'E	8,501	(2592.8)
3	S37°00'E	7,630	(2327.2)
4	S42°10'E	6,838	(2085.6)

Bearing and distance is from well site to SW corner of Section 18, T20N, R52E.

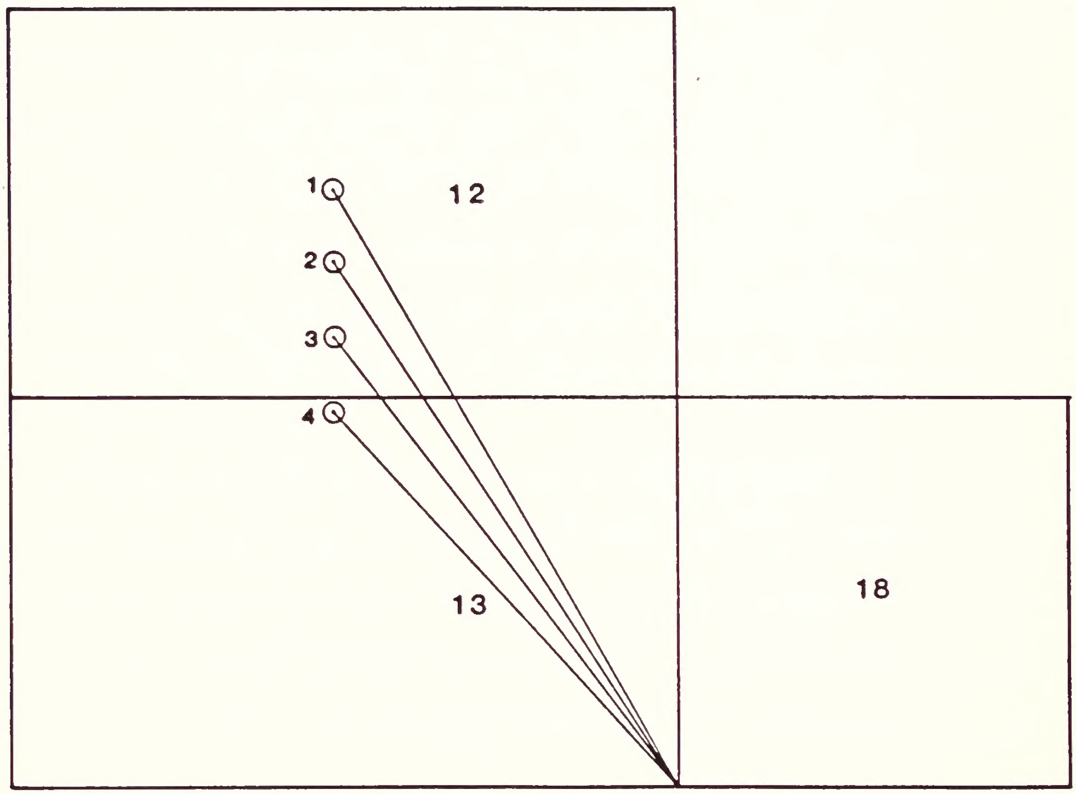
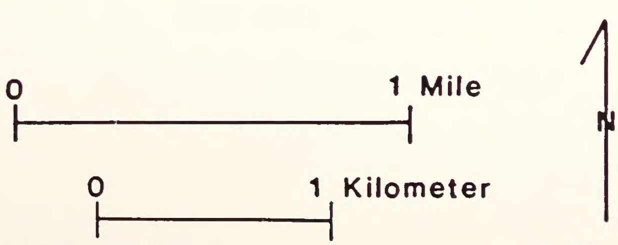


FIGURE B-2

WELL LOCATIONS

KOBEH "B" WELL FIELD



PROJECT 1298-82
DATE March 1982
REVISIONS

Hydro-Search, Inc.
CONSULTING HYDROLOGISTS-GEOLOGISTS
Austin • Denver • Reno

EXXON MINERALS COMPANY
MT. HOPE PROJECT
PHASE I HYDROLOGY

Well Field Summary

Well Field Name ___Kobeh B___ Priority Ranking

A. Well Field vs. Well Field _4_

B. Within Basin _3_

I. WATER RIGHTS ACQUISITION

A. Basin Name ___Kobeh Valley___ Designated-yes ____ no _X_

B. Points of Diversion (Well Locations)

See Figure B-2

1. ? 1/4, ? 1/4, Sec.12, T.20N., R.51E., M.D.B. & M. (unsurveyed)
2. ? 1/4, ? 1/4, Sec.12, T.20N., R.51E., M.D.B. & M. (unsurveyed)
3. ? 1/4, ? 1/4, Sec.12, T.20N., R.51E., M.D.B. & M. (unsurveyed)
4. ? 1/4, ? 1/4, Sec.13, T.20N., R.51E., M.D.B. & M. (unsurveyed)

C. Surface Elevation (above Mean Sea Level, USGS Datum)

1. 6033 ft. (1840.1 m) Est. from Topo Map _X_, Surveyed ______
2. 6030 ft. (1839.2 m) Est. from Topo Map _X_, Surveyed ______
3. 6023 ft. (1837.0 m) Est. from Topo Map _X_, Surveyed ______
4. 6019 ft. (1835.8 m) Est. from Topo Map _X_, Surveyed ______

D. Nearest Well or Permit

1. Permit Number _23359_
2. Owner _Hoekenga Cattle Co._
3. Status of Permit—Certificated _Yes_ Permitted ____ Pending ____
4. Flow Rate _6.0_ cfs (_169.9_ lps)
5. Distance from Well Field _0.5_ mi (_0.81_ km), _Southeast_

E. Possible Problems with Water Rights Acquisition

This well field is located on the valley floor where agriculture is more intense. There are about seven other permits 1 to 2 miles (1.6 to 3.2 km) southeast. Although the basin is undesignated, some protests can be expected.

II. HYDROGEOLOGIC DATA

A. Primary Aquifer

1. Geologic Unit Quaternary-Tertiary alluvium

2. Aquifer Materials Sand and gravel interbedded and intermixed with silt and clay

3. Saturated Thickness 850 ft (259.3 m)

4. Static Water Level

a. Depth below Surface 10 ft (3.1 m)

b. Elevation 6020 ft (1836.1m)

c. Estimated X, Measured _____ Date _____

5. Aquifer Parameters

a. Source, Pumping Test-yes ____ no X

Description _____

Other Source-yes X no ____

Explanation Estimated from similar materials in other alluvial basins in Nevada

b. Transmissivity (T) 170,000 gpd/ft (2108.0 m^2/d)

c. Hydraulic Conductivity (K) 200 gpd/ft^2 (8.1 m/d)

d. Storage Coefficient (S) 1×10^{-2}

7. Possible Boundaries None

B. Water Quality

1. Total Dissolved Solids (TDS) 200-500 mg/l

2. Electrical Conductivity (EC) ______ μmhos/cm @ 25°C

3. Temperature _____ °C

4. General Water Type Calcium bicarbonate and sodium bicarbonate

5. Problem Constituents Manganese and iron may be high

6. Possible Treatment Necessary Not enough data available for evaluation

III. WELL FIELD DESIGN CRITERIA

A. General

1. Number of Wells

a. Primary __2__

b. Backup __2__

c. Total Number __4__

2. Capacity __2700__ gpm (__170.4__ lps)

3. Spacing __1000__ ft (__305.0__ m)

4. Total depth __860__ ft (__262.3__ m)

B. Well Design

1. Hole Diameter ____ in. (______ cm)

2. Drilling Method ____

____

____

____

3. Casing Requirements

a. Surface Casing

Type ____

Diameter ________ in. (________ cm)

Wall Thickness _________ in. (__________ cm)

Length _____ ft (_________ m)

Installation Depth from _____ ft (______ m) to _____ ft

(_____ m) below surface

Seal ____

____

____

b. Production Casing

Type ____

Diameter _________in. (_________cm)

Wall Thickness _________in. (___________cm)

Length ______ft (__________m)

Installation ____

____

____

____

c. Screen

Type ____

Diameter _______in. (________cm)

Size of Openings ______in. (_______cm)

Total Length ______ft (_______m)

Installation ____

____

____

____

4. Gravel Pack

a. Grain Size ____

____

b. Placement from _____ft (______m) to ______ft (_______m)

below surface

c. Installation ______________________________________

____

____

____

d. Seal ____

____

____

____

C. Pump Design

1. Anticipated Pumping Water Level 110 ft (33.6 m) below Surface; 5920 ft (1805.6 m) Elevation

2. Head Loss due to Pump Column _____ft (_____m)

3. Total Dynamic Head _____ft (_____m)

4. Pump Requirements

a. Type ____

b. Motor ______HP (_______Kw)

c. Number of Stages ______

d. Diameter of Pump Column _____in. (_____cm)

e. Pump Setting _____ft (_____m) below Surface

_____ft (_____m) Elevation

D. Pipe Line Design

1. Lift from Well Field to Mill 831 ft (253.5 m)

2. Length of Pipeline

a. Tie Line Between Wells 3000 ft (915.0 m)

b. Well Field to Mill 62600 ft (19093.0 m) or

11.9 mi (19.2 km)

3. Diameter of Pipeline

a. Tie Line _____in. (_____cm)

b. Transmission Line _____in. (_____cm)

E. Estimated Costs for Wells and Pumps

1. Well Drilling and Completion

   $_________ per well x _____ wells = $_________Total for Well Field

2. Pumps (including installation)

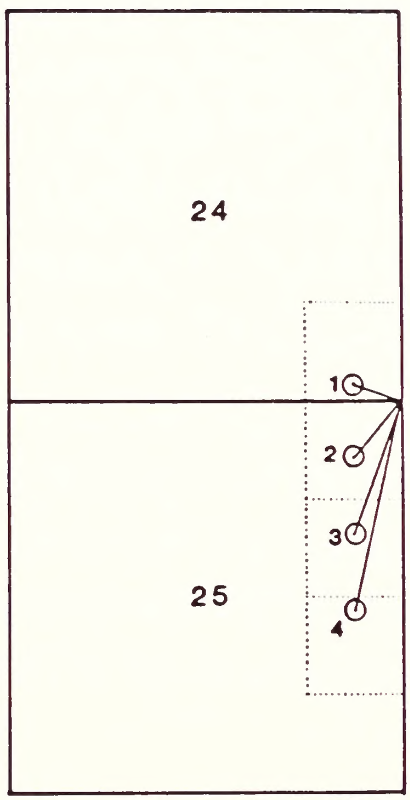
   $_________ per installation x _____ wells = $_________ Total for Well Field

3. Total Estimate for Well Field $_________

EXXON MINERALS COMPANY
KOBEH "C" WELL FIELD
EUREKA COUNTY, NEVADA

WELL SITE	BEARING	DISTANCE, feet	(m)
1	S71°00'E	686	(209.2)
2	N39°40'E	1,003	(305.9)
3	N19°55'E	1,901	(579.8)
4	N13°10'E	2,878	(878.1)

Bearing and distance is from well site to SE corner of Section 24.



T 21 N, R 51 E

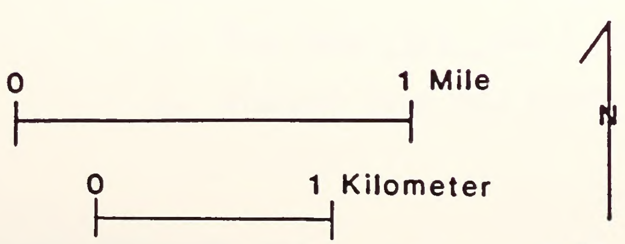


FIGURE B-3

WELL LOCATIONS

KOBEH "C" WELL FIELD

PROJECT 1298-82	REVISIONS
DATE March 1982	

Hydro-Search, Inc.
CONSULTING HYDROLOGISTS-GEOLOGISTS
Austin • Denver • Reno

EXXON MINERALS COMPANY
MT. HOPE PROJECT
PHASE I HYDROLOGY

Well Field Summary

Well Field Name Kobeh C

Priority Ranking

A. Well Field vs. Well Field ___

B. Within Basin 1

I. WATER RIGHTS ACQUISITION

A. Basin Name Kobeh Valley Designated-yes ____ no X

B. Points of Diversion (Well Locations)

1. SE 1/4, SE 1/4, Sec.24, T.21N., R.51E., M.D.B. & M.
2. NE 1/4, NE 1/4, Sec.25, T.21N., R.51E., M.D.B. & M.
3. SE 1/4, NE 1/4, Sec.25, T.21N., R.51E., M.D.B. & M.
4. NE 1/4, SE 1/4, Sec.25, T.21N., R.51E., M.D.B. & M.

C. Surface Elevation (above Mean Sea Level, USGS Datum)

1. 6150 ft. (1875.8 m) Est. from Topo Map X, Surveyed ______
2. 6145 ft. (1874.2 m) Est. from Topo Map X, Surveyed ______
3. 6135 ft. (1871.2 m) Est. from Topo Map X, Surveyed ______
4. 6130 ft. (1869.7 m) Est. from Topo Map X, Surveyed ______

D. Nearest Well or Permit

1. Permit Number 42856
2. Owner MX
3. Status of Permit—Certificated ____ Permitted Yes Pending ____
4. Flow Rate 2.0 cfs (56.6 lps)
5. Distance from Well Field 1.8 mi (2.9 km), North

E. Possible Problems with Water Rights Acquisition

This well field is located away from the more developed valley floor and is in an undesignated basin. Therefore, few water rights acquisition problems are anticipated.

II. HYDROGEOLOGIC DATA

A. Primary Aquifer

1. Geologic Unit Eastern Assemblage Formations

2. Aquifer Materials Fractures and solution features in limestones and dolomite

3. Saturated Thickness 300 ft (91.5 m)

4. Static Water Level (SEE STATIC WATER LEVEL IN ALLUVIUM BELOW)

a. Depth below Surface ____ft (____m)

b. Elevation ____ft (____m)

c. Estimated X, Measured ____ Date ____

5. Aquifer Parameters

a. Source, Pumping Test-yes ____ no X

Description ____

Other Source-yes X no ____

Explanation Estimated from Eastern Assemblage in other areas

of Nevada

b. Transmissivity (T) 150,000 gpd/ft (1860.0 m^2/d)

c. Hydraulic Conductivity (K) 500 gpd/ft^2 (20.4 m/d)

d. Storage Coefficient (S) 1×10^{-2}

6. Possible Boundaries Tertiary igneous intrusion (Whister Mountain) approximately 2 miles (3.2 km) east-southeast

B. Secondary Aquifer

1. Geologic Unit Quaternary-Tertiary alluvium

2. Aquifer Materials Sand and gravel interbedded and intermixed with silt and clay

3. Saturated Thickness 500 ft (152.5 m)

4. Static Water Level

a. Depth below Surface 100 ft (30.5 m)

b. Elevation 6040 ft (1842.2 m)

c. Estimated X, Measured ______ Date ______

5. Aquifer Parameters

a. Source, Pumping Test-yes ____ no X

Description

Other Source-yes X no ___

Explanation Estimated from materials in other alluvial basins in Nevada

b. Transmissivity (T) 100,000 gpd/ft (1240.0 m^2/d)

c. Hydraulic Conductivity (K) 200 gpd/ft^2 (8.1 m/d)

d. Storage Coefficient (S) 1×10^{-2}

6. Possible Boundaries None

C. Water Quality

1. Total Dissolved Solids (TDS) 200-500 mg/l

2. Electrical Conductivity (EC) ______ µmhos/cm @ 25°C

3. Temperature _____ °C

4. General Water Type Calcium bicarbonate and sodium bicarbonate

5. Problem Constituents Manganese and iron may be high

6. Possible Treatment Necessary Not enough data available for evaluation

VII. WELL FIELD DESIGN CRITERIA

A. General

1. Number of Wells

a. Primary __2__

b. Backup __2__

c. Total Number __4__

2. Capacity __2700__ gpm (__170.4__ lps)

3. Spacing __1000__ ft (__305.0__ m)

4. Total Depth __900__ ft (__274.5__ m)

B. Well Design

1. Hole Diameter _____ in. (______ cm)

2. Drilling Method ____

____

____

____

3. Casing Requirements

a. Surface Casing

Type ____

Diameter _________ in. (_________ cm)

Wall Thickness _________ in. (__________ cm)

Length ______ ft (_________ m)

Installation Depth from _____ ft (______ m) to _____ ft

(_____ m) below surface

Seal ____

____

____

b. Production Casing

Type ____

Diameter __________in. (__________cm)

Wall Thickness __________in. (____________cm)

Length _______ft (__________m)

Installation ______________________________________

____

____

____

c. Screen

Type ____

Diameter ________in. (_________cm)

Size of Openings _______in. (________cm)

Total Length _______ft (________m)

Installation ______________________________________

____

____

____

4. Gravel Pack

a. Grain Size ______________________________________

____

b. Placement from ______ft (_______m) to _______ft (________m) below surface

c. Installation ______________________________________

____

____

____

d. Seal ____

____

____

____

C. Pump Design

1. Anticipated Pumping Water Level 170 ft (51.9 m) below Surface; 6000 ft (1830.0 m) Elevation

2. Head Loss due to Pump Column _______ft (________m)

3. Total Dynamic Head _______ft (________m)

4. Pump Requirements

a. Type ____

b. Motor ______HP (_______Kw)

c. Number of Stages ______

d. Diameter of Pump Column _____in. (______cm)

e. Pump Setting _____ft (______m) below Surface

_____ft (______m) Elevation

D. Pipe Line Design

1. Lift from Well Field to Mill 720 ft (219.6 m)

2. Length of Pipeline

a. Tie Line Between Wells 3000 ft (915.0 m)

b. Well Field to Mill 43800 ft (13359.0 m) or

8.3 mi (13.4 km)

3. Diameter of Pipeline

a. Tie Line _____in. (______cm)

b. Transmission Line _____in. (_____cm)

E. Estimated Costs for Wells and Pumps

1. Well Drilling and Completion

$\$$_________ per well x _____ wells = $\$$_________Total for Well Field

2. Pumps (including installation)

$\$$_________ per installation x _____ wells = $\$$_________ Total for Well Field

3. Total Estimate for Well Field $\$$_________

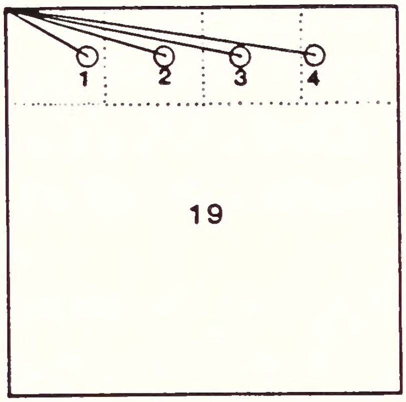
EXXON MINERALS COMPANY

DIAMOND "A" WELL FIELD

EUREKA COUNTY, NEVADA

WELL SITE	BEARING	DISTANCE, feet	(m)
1	N58°55'W	1,267	(386.4)
2	N73°05'W	2,191	(668.3)
3	N78°05'W	3,194	(974.2)
4	N80°50'W	4,198	(1280.4)

Bearing and distance is from well site to NW corner of Section 19.



T 22 N, R 53 E

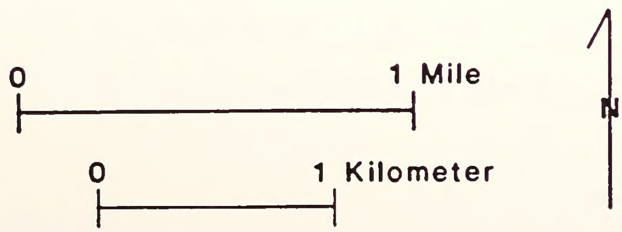


FIGURE B-4

WELL LOCATIONS

DIAMOND "A" WELL FIELD

PROJECT 1298-82	REVISIONS
DATE March 1982	

Hydro-Search, Inc.

CONSULTING HYDROLOGISTS-GEOLOGISTS

Austin • Denver • Reno

EXXON MINERALS COMPANY
MT. HOPE PROJECT
PHASE I HYDROLOGY

Well Field Summary

Well Field Name Diamond A

Priority Ranking

A. Well Field vs Well Field 5

B. Within Basin 2

I. WATER RIGHTS ACQUISITION

A. Basin Name Diamond Valley Designated-yes X no ____

B. Points of Diversion (Well Locations)

1. NW 1/4, NW 1/4, Sec.19, T.22N., R.53E., M.D.B. & M.
2. NE 1/4, NW 1/4, Sec.19, T.22N., R.53E., M.D.B. & M.
3. NW 1/4, NE 1/4, Sec.19, T.22N., R.53E., M.D.B. & M.
4. NE 1/4, NE 1/4, Sec.19, T.22N., R.53E., M.D.B. & M.

C. Surface Elevation (above Mean Sea Level, USGS Datum)

1. 5850 ft. (1784.3 m) Est. from Topo Map X, Surveyed ____
2. 5850 ft. (1784.3 m) Est. from Topo Map X, Surveyed ____
3. 5850 ft. (1784.3 m) Est. from Topo Map X, Surveyed ____
4. 5850 ft. (1784.3 m) Est. from Topo Map X, Surveyed ____

D. Nearest Well or Permit

1. Permit Number 41186
2. Owner unknown
3. Status of Permit-Certificated ____ Permitted Yes Pending ____
4. Flow Rate 1.0 cfs (28.3 lps)
5. Distance from Well Field 1.2 mi (1.9 km), west-southwest

E. Possible Problems with Water Rights Acquisition

The valley floor of Diamond Valley is designated. Given the past controversies over water rights in the valley, many protests and significant problems are anticipated in acquiring water rights.

II. HYDROGEOLOGIC DATA

A. Primary Aquifer

1. Geologic Unit Quaternary-Tertiary alluvium

2. Aquifer Materials Sand and gravel strata interbedded with silts and clays.

3. Saturated Thickness 350 ft (106.8 m)

4. Static Water Level

a. Depth below Surface 20 ft (6.10 m)

b. Elevation 5830 ft (1778.2 m)

c. Estimated X , Measured ____ Date ____

5. Aquifer Parameters

a. Source, Pumping Test-yes ____ no X

Description ____

Other Source-yes X no ____

Explanation Estimated from aquifer tests in other basins in Nevada.

b. Transmissivity (T) 262,500 gpd/ft (3255.0 m^2/d)

c. Hydraulic Conductivity (K) 750 gpd/ft^2 (30.5 m/d)

d. Storage Coefficient (S) 0.1

7. Possible Boundaries None

B. Water Quality

1. Total Dissolved Solids (TDS) 200-500 mg/l

2. Electrical Conductivity (EC) 400-600 μmhos/cm @ 25°C

3. Temperature ≃ 30 °C

4. General Water Type Calcium bicarbonate, sodium bicarbonate, and calcium sodium bicarbonate

5. Problem Constituents Iron and manganese may be high

6. Possible Treatment Necessary Not enough data available for evaluation

III. WELL FIELD DESIGN CRITERIA

A. General

1. Number of Wells

   a. Primary __2__

   b. Backup __2__

   c. Total Number __4__

2. Capacity __2700__ gpm (__170.4__ lps)

3. Spacing __1000__ ft (__305.0__ m)

4. Total depth __370__ ft (__112.9__ m)

B. Well Design

1. Hole Diameter ____ in. (______ cm)

2. Drilling Method ________________________________

   ____

   ____

   ____

3. Casing Requirements

   a. Surface Casing

      Type ____

      Diameter ________ in. (________ cm)

      Wall Thickness ________ in. (__________ cm)

      Length ______ ft (_________ m)

      Installation Depth from _____ ft (______ m) to _____ ft (_____ m) below surface

      Seal ____

      ____

      ____

b. Production Casing

Type ____

Diameter _________in. (_________cm)

Wall Thickness _________in. (___________cm)

Length ______ft (__________m)

Installation ____

____

____

____

c. Screen

Type ____

Diameter _______in. (________cm)

Size of Openings _______in. (________cm)

Total Length ______ft (_______m)

Installation ____

____

____

____

4. Gravel Pack

a. Grain Size ____

____

b. Placement from ______ft (______m) to _______ft (_______m) below surface

c. Installation ____

____

____

____

d. Seal ____

____

____

____

C. Pump Design

1. Anticipated Pumping Water Level 90 ft (27.5 m) below Surface; 5760 ft (1756.8 m) Elevation

2. Head Loss due to Pump Column _____ft (______m)

3. Total Dynamic Head _____ft (______m)

4. Pump Requirements

a. Type ____

b. Motor ______HP (______Kw)

c. Number of Stages ______

d. Diameter of Pump Column _____in. (______cm)

e. Pump Setting _____ft (______m) below Surface

_____ft (______m) Elevation

D. Pipe Line Design

1. Lift from Well Field to Mill 850 ft (259.3 m)

2. Length of Pipeline

a. Tie Line Between Wells 3000 ft (915.0 m)

b. Well Field to Mill 37100 ft (11315.5 m) or

7.0 mi (11.3 km)

3. Diameter of Pipeline

a. Tie Line _____in. (______cm)

b. Transmission Line _____in. (______cm)

E. Estimated Costs for Wells and Pumps

1. Well Drilling and Completion

   $________ per well x _____ wells = $_________Total for Well Field

2. Pumps (including installation)

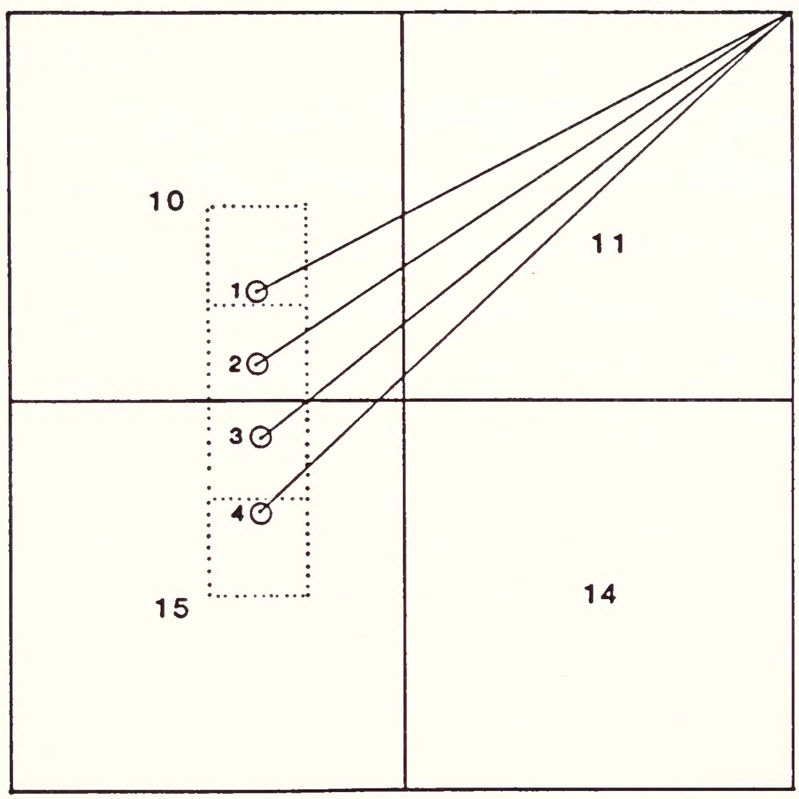
   $_________ per installation x _____ wells = $_________ Total for Well Field

3. Total Estimate for Well Field $_________

EXXON MINERALS COMPANY
DIAMOND "B" WELL FIELD
EUREKA COUNTY, NEVADA

WELL SITE	BEARING	DISTANCE, feet	(m)
1	N62°25'E	8,184	(2495.2)
2	N56°35'E	8,686	(2649.2)
3	N51°20'E	9,240	(2818.2)
4	N46°55'E	9,926	(3027.4)

Bearing and distance is from well site to NE corner of Section 11.



T 22 N, R 52 E

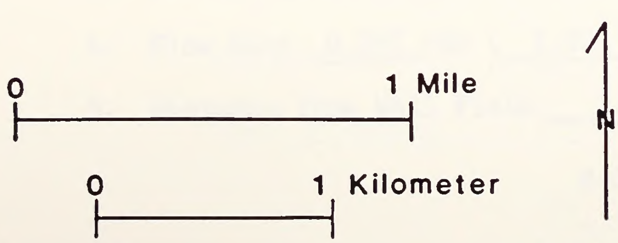


FIGURE B-5

WELL LOCATIONS

DIAMOND "B" WELL FIELD

PROJECT 1298-82

DATE March 1982

REVISIONS

Hydro-Search, Inc.
CONSULTING HYDROLOGISTS-GEOLOGISTS
Austin • Denver • Reno

EXXON MINERALS COMPANY
MT. HOPE PROJECT
PHASE I HYDROLOGY

Well Field Summary

Well Field Name Diamond B

Priority Ranking

A. Well Field vs Well Field 2

B. Within Basin 1

I. WATER RIGHTS ACQUISITION

A. Basin Name Diamond Valley Designated-yes ____ no X

B. Points of Diversion (Well Locations)

1. NW 1/4, SE 1/4, Sec.10, T.22N., R.52E., M.D.B. & M. (unsurveyed)
2. SW 1/4, SE 1/4, Sec.10, T.22N., R.52E., M.D.B. & M. (unsurveyed)
3. NW 1/4, NE 1/4, Sec.15, T.22N., R.52E., M.D.B. & M. (unsurveyed)
4. SW 1/4, NE 1/4, Sec.15, T.22N., R.52E., M.D.B. & M. (unsurveyed)

C. Surface Elevation (above Mean Sea Level, USGS Datum)

1. 6010 ft. (1833.1 m) Est. from Topo Map X, Surveyed ____
2. 6000 ft. (1820.0 m) Est. from Topo Map X, Surveyed ____
3. 5995 ft. (1828.5 m) Est. from Topo Map X, Surveyed ____
4. 6020 ft. (1836.1 m) Est. from Topo Map X, Surveyed ____

D. Nearest Well or Permit

1. Permit Number 11004
2. Owner Formerly A.C. Florio but probably has been reassigned.
3. Status of Permit-Certificated Yes Permitted ____ Pending ____
4. Flow Rate 0.095 cfs (2.69 lps)
5. Distance from Well Field 1.0 mi (1.6 km), East

E. Possible Problems with Water Rights Acquisition

This well field is located in the undesignated portion of Diamond Valley but protests from water rights permit owners in the designated basin can be anticipated. It is possible that the Nevada State Engineer may designate the entire hydrographic basin as a result of this application.

II. HYDROGEOLOGIC DATA

A. Primary Aquifer

1. Geologic Unit Eastern Assemblage Formations

2. Aquifer Materials Fractures and solution features in limestone and dolomite

3. Saturated Thickness 500 ft (152.5 m)

4. Static Water Level

   a. Depth below Surface 150 ft (45.8 m)

   b. Elevation 5850 ft (1784.3 m)

   c. Estimated X, Measured ______ Date ______

5. Aquifer Parameters

   a. Source, Pumping Test-yes ___ no X

   Description ______

   Other Source-yes X no ___

   Explanation Estimated from Eastern Assemblage in other areas of Nevada

b. Transmissivity (T) 250,000 gpd/ft (3100.0 m^2/d)

c. Hydraulic Conductivity (K) 500 gpd/ft^2 (20.4 m/d)

d. Storage Coefficient (S) 1×10^{-2}

7. Possible Boundaries None

B. Water Quality

1. Total Dissolved Solids (TDS) 200-500 mg/l
2. Electrical Conductivity (EC) 400-600 μmhos/cm @ 25°C
3. Temperature ≃ 30 °C
4. General Water Type Calcium bicarbonate, sodium bicarbonate, and calcium sodium bicarbonate
5. Problem Constituents Iron and manganese may be high
6. Possible Treatment Necessary Not enough data available for evaluation

III. WELL FIELD DESIGN CRITERIA

A. General

1. Number of Wells

   a. Primary __2__

   b. Backup __2__

   c. Total Number __4__

2. Capacity __2700__ gpm (__170.4__ lps)

3. Spacing __1000__ ft (__305.0__ m)

4. Total depth __650__ ft (__198.3__ m)

B. Well Design

1. Hole Diameter ____ in. (______ cm)

2. Drilling Method ______________________________________

   ____

   ____

   ____

3. Casing Requirements

   a. Surface Casing

      Type ____

      Diameter ________ in. (________ cm)

      Wall Thickness ________ in. (__________ cm)

      Length _____ ft (_________ m)

      Installation Depth from _____ ft (______ m) to _____ ft (_____ m) below surface

      Seal ____

      ____

      ____

b. Production Casing

Type ____

Diameter ________in. (________cm)

Wall Thickness ________in. (__________cm)

Length ______ft (_________m)

Installation _____________________________________

____

____

____

c. Screen

Type ____

Diameter _______in. (________cm)

Size of Openings ______in. (_______cm)

Total Length ______ft (_______m)

Installation _____________________________________

____

____

____

4. Gravel Pack

a. Grain Size _______________________________________

____

b. Placement from _____ft (______m) to ______ft (_______m)

below surface

c. Installation _____________________________________

____

____

____

d. Seal ____

____

____

____

C. Pump Design

1. Anticipated Pumping Water Level 220 ft (67.1 m) below Surface; 5780 ft (1762.9 m) Elevation

2. Head Loss due to Pump Column _____ft (______m)

3. Total Dynamic Head _____ft (_____m)

4. Pump Requirements

a. Type ____

b. Motor ______HP (_______Kw)

c. Number of Stages ______

d. Diameter of Pump Column _____in. (_____cm)

e. Pump Setting _____ft (______m) below Surface

_____ft (_____m) Elevation

D. Pipe Line Design

1. Lift from Well Field to Mill 700 ft (213.5 m)

2. Length of Pipeline

a. Tie Line Between Wells 3000 ft (915.0 m)

b. Well Field to Mill 24500 ft (7472.5 m) or

4.6 mi (7.4 km)

3. Diameter of Pipeline

a. Tie Line _____in. (______cm)

b. Transmission Line _____in. (______cm)

E. Estimated Costs for Wells and Pumps

1. Well Drilling and Completion

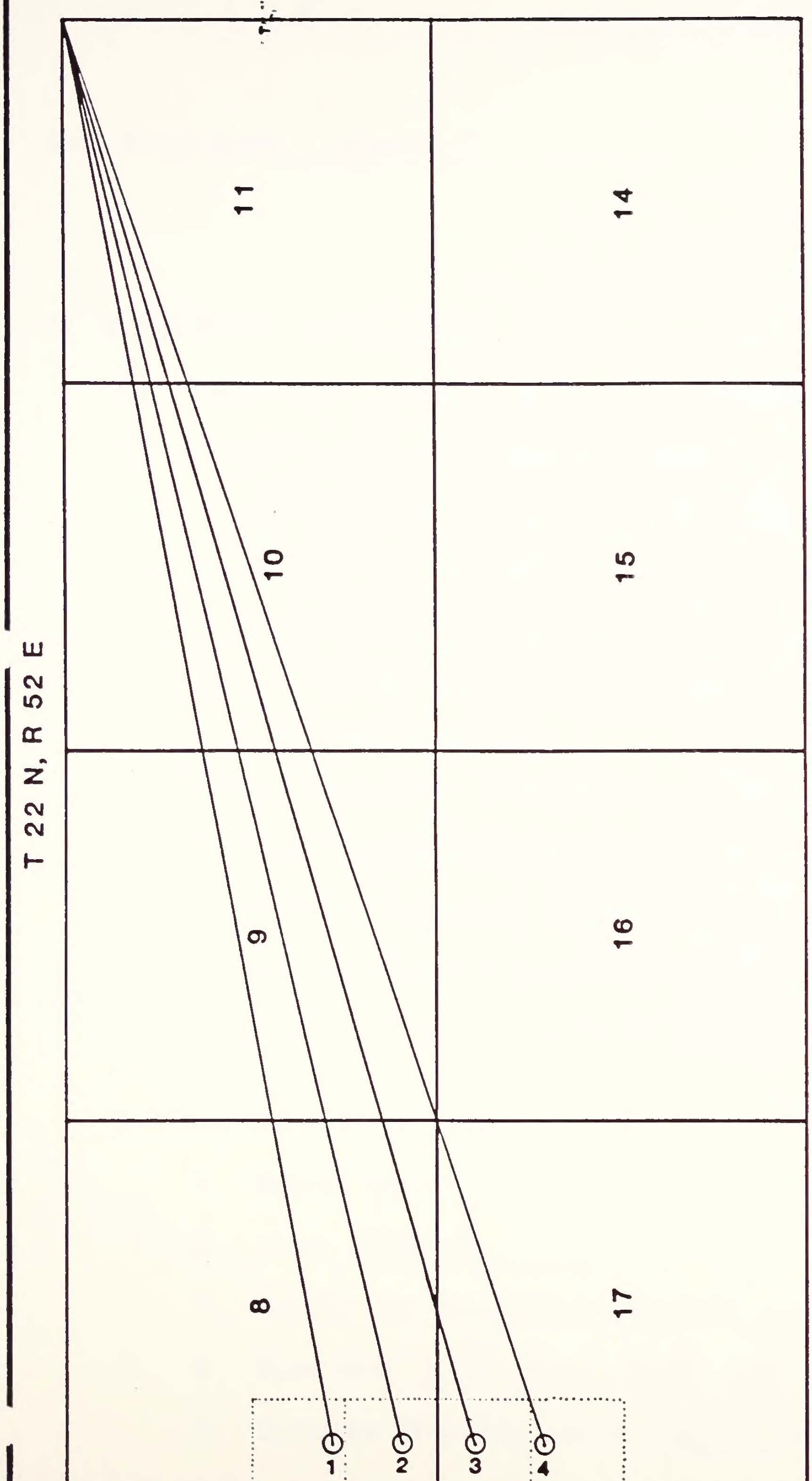
   $________ per well x ____ wells = $________Total for Well Field

2. Pumps (including installation)

   $________ per installation x ____ wells = $________ Total for Well Field

3. Total Estimate for Well Field $________

EXXON MINERALS COMPANY
DIAMOND "C" WELL FIELD
EUREKA COUNTY, NEVADA



WELL SITE	BEARING	DISTANCE, feet (m)
1	N79°15'E	20,724 (6320.8)
2	N76°40'E	20,909 (6377.3)
3	N74°00'E	21,173 (6457.8)
4	N71°20'E	21,463 (6546.2)

Bearing and distance is from well site to NE corner of Section 11.

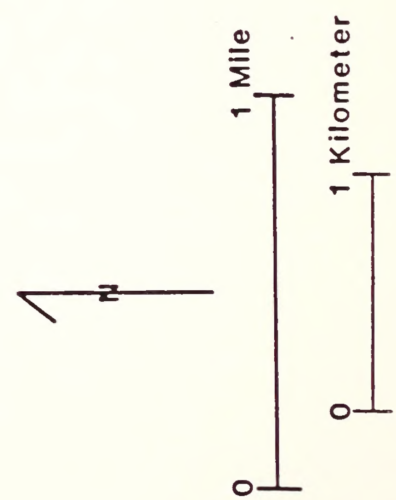


FIGURE B-6

WELL LOCATIONS

DIAMOND "C" WELL FIELD

PROJECT 1298-82	REVISIONS
DATE March 1982	

Hydro-Search, Inc.
CONSULTING HYDROLOGISTS-GEOLOGISTS
Austin • Denver • Reno

EXXON MINERALS COMPANY
MT. HOPE PROJECT
PHASE I HYDROLOGY

Well Field Summary

Well Field Name Diamond C

Priority Ranking

A. Well Field vs Well Field 8

B. Within Basin 3

I. WATER RIGHTS ACQUISITION

A. Basin Name Diamond Valley Designated-yes ____ no X

B. Points of Diversion (Well Locations)

1. NW 1/4, SW 1/4, Sec. 8, T.22N., R.52E., M.D.B. & M.
2. SW 1/4, SW 1/4, Sec. 8, T.22N., R.52E., M.D.B. & M.
3. NW 1/4, NW 1/4, Sec.17, T.22N., R.52E., M.D.B. & M.
4. SW 1/4, NW 1/4, Sec.17, T.22N., R.52E., M.D.B. & M.

C. Surface Elevation (above Mean Sea Level, USGS Datum)

1. 6285 ft. (1916.9 m) Est. from Topo Map X, Surveyed ____
2. 6280 ft. (1915.4 m) Est. from Topo Map X, Surveyed ____
3. 6275 ft. (1913.9 m) Est. from Topo Map X, Surveyed ____
4. 6275 ft. (1913.9 m) Est. from Topo Map X, Surveyed ____

D. Nearest Well or Permit

1. Permit Number 43085
2. Owner Unknown
3. Status of Permit-Certificated ____ Permitted Yes Pending ____
4. Flow Rate 0.97 cfs (27.47 lps)
5. Distance from Well Field 0.4 mi (0.6 km), West

E. Possible Problems with Water Rights Acquisition

Because this well field is in the undesignated portion of Diamond Valley and is away from agricultural development at the valley floor, few problems with water rights acquisition are anticipated.

II. HYDROGEOLOGIC DATA

A. Primary Aquifer

1. Geologic Unit Eastern Assemblage Formations
2. Aquifer Materials Fractures and solution features in limestone and dolomite
3. Saturated Thickness 500 ft (152.5 m)
4. Static Water Level
   a. Depth below Surface 275 ft (83.9 m)
   b. Elevation 6000 ft (1830.0 m)
   c. Estimated X, Measured _____ Date _____
5. Aquifer Parameters
   a. Source, Pumping Test-yes ____ no X

   Description

   Other Source-yes X no ____

   Explanation Estimated based on Eastern Assemblage in other areas of Nevada

b. Transmissivity (T) 250,000 gpd/ft (3100.0 m^2/d)

c. Hydraulic Conductivity (K) 500 gpd/ft^2 (20.4 m/d)

d. Storage Coefficient (S) 5×10^{-4}

7. Possible Boundaries Tertiary intrusives forming host rock for Mt. Hope mineralization occur to depth about 1 mile to the west.

B. Water Quality

1. Total Dissolved Solids (TDS) 200-500 mg/l

2. Electrical Conductivity (EC) 400-600 μmhos/cm @ 25°C

3. Temperature ≈ 30 °C

4. General Water Type Calcium bicarbonate, sodium bicarbonate, and calcium sodium bicarbonate

5. Problem Constituents Iron and manganese may be high

6. Possible Treatment Necessary Not enough data available for evaluation

III. WELL FIELD DESIGN CRITERIA

A. General

1. Number of Wells

a. Primary 2

b. Backup 2

c. Total Number 4

2. Capacity 2700 gpm (170.4 lps)

3. Spacing 1000 ft (305.0 m)

4. Total depth 3100 ft (945.5 m)

B. Well Design

1. Hole Diameter ____in. (______cm)

2. Drilling Method ____

____

____

____

3. Casing Requirements

a. Surface Casing

Type ____

Diameter ________in. (________cm)

Wall Thickness ________in. (__________cm)

Length ______ft (_________m)

Installation Depth from _____ft (______m) to _____ft

(_____m) below surface

Seal ____

____

____

b. Production Casing

Type ____

Diameter ________ in. (________ cm)

Wall Thickness ________ in. (__________ cm)

Length ______ ft (_________ m)

Installation ______________________________________

____

____

____

c. Screen

Type ____

Diameter _______ in. (________ cm)

Size of Openings ______ in. (_______ cm)

Total Length ______ ft (_______ m)

Installation ______________________________________

____

____

____

4. Gravel Pack

a. Grain Size ______________________________________

____

b. Placement from _____ ft (______ m) to ______ ft (_______ m) below surface

c. Installation ______________________________________

____

____

____

d. Seal ______________________________

____

____

____

C. Pump Design

1. Anticipated Pumping Water Level 360 ft (109.8 m) below Surface; 5910 ft (1802.6 m) Elevation

2. Head Loss due to Pump Column _____ft (_____m)

3. Total Dynamic Head _____ft (_____m)

4. Pump Requirements

a. Type ______________________________

b. Motor _____HP (_____Kw)

c. Number of Stages _____

d. Diameter of Pump Column _____in. (_____cm)

e. Pump Setting _____ft (_____m) below Surface

_____ft (_____m) Elevation

D. Pipe Line Design

1. Lift from Well Field to Mill 425 ft (129.6 m)

2. Length of Pipeline

a. Tie Line Between Wells 3000 ft (915.0 m)

b. Well Field to Mill 11500 ft (3507.5 m) or

2.2 mi (3.5 km)

3. Diameter of Pipeline

a. Tie Line _____in. (_____cm)

b. Transmission Line _____in. (_____cm)

E. Estimated Costs for Wells and Pumps

1. Well Drilling and Completion

   $_________ per well x _____ wells = $_________Total for Well Field

2. Pumps (including installation)

   $_________ per installation x _____ wells = $_________ Total for Well Field

3. Total Estimate for Well Field $_________

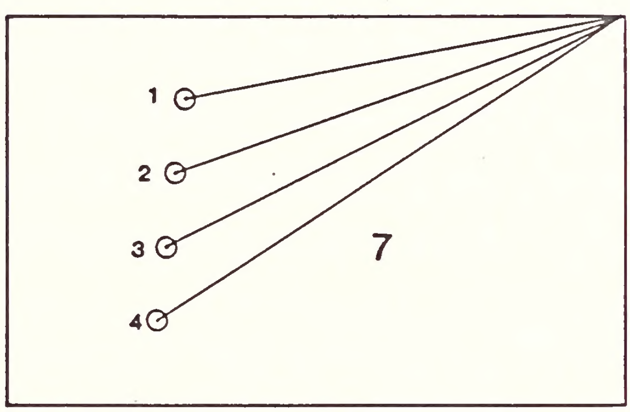
EXXON MINERALS COMPANY

GARDEN "A" WELL FIELD

EUREKA COUNTY, NEVADA

WELL SITE	BEARING	DISTANCE, feet	(m)
1	N56°50'E	6,019	(1835.8)
2	N63°10'E	6,389	(1948.7)
3	N70°40'E	6,917	(2109.7)
4	N79°15'E	7,524	(2294.8)

Bearing and distance is from well site to NW corner of Section 7.



T 22 N, R 52 E

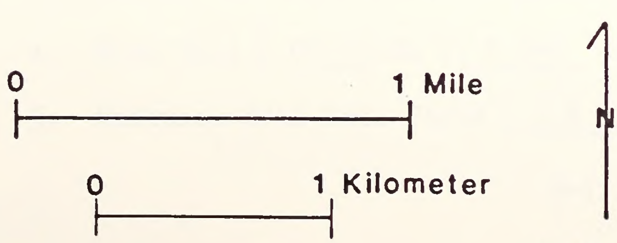


FIGURE B-7

WELL LOCATIONS

GARDEN "A" WELL FIELD

PROJECT 1298-82	REVISIONS
DATE March 1982	

Hydro-Search, Inc.
CONSULTING HYDROLOGISTS-GEOLOGISTS
Austin • Denver • Reno

EXXON MINERALS COMPANY
MT. HOPE PROJECT
PHASE I HYDROLOGY

Well Field Summary

Well Field Name Garden A

Priority Ranking

A. Well Field vs Well Field 9

B. Within Basin 3

I. WATER RIGHTS ACQUISITION

A. Basin Name Garden/Pine Valley Designated-yes ____ no X

B. Points of Diversion (Well Locations)

1. ? 1/4, ? 1/4, Sec. 7, T.23N., R.52E., M.D.B. & M.

See

2. ? 1/4, ? 1/4, Sec. 7, T.23N., R.52E., M.D.B. & M.

Figure

3. ? 1/4, ? 1/4, Sec. 7, T.23N., R.52E., M.D.B. & M.

B-7

4. ? 1/4, ? 1/4, Sec. 7, T.23N., R.52E., M.D.B. & M.

C. Surface Elevation (above Mean Sea Level, USGS Datum)

1. 6320 ft. (1927.6 m) Est. from Topo Map X, Surveyed ____

2. 6320 ft. (1927.6 m) Est. from Topo Map X, Surveyed ____

3. 6340 ft. (1933.7 m) Est. from Topo Map X, Surveyed ____

4. 6340 ft. (1933.7 m) Est. from Topo Map X, Surveyed ____

D. Nearest Well or Permit

1. Permit Number 6911

2. Owner Eureka-Nevada Railroad

3. Status of Permit-Certificated Yes Permitted ____ Pending ____

4. Flow Rate 0.00155cfs (0.044 lps)

5. Distance from Well Field 1.6 mi (2.6 km), South-southeast

E. Possible Problems with Water Rights Acquisition

Garden/Pine Valley is undesignaged and the well field is located away from agricultural development. Therefore, few problems with water rights acquisition are anticipated.

II. HYDROGEOLOGIC DATA

A. Primary Aquifer

1. Geologic Unit Eastern Assemblage Formations

2. Aquifer Materials Fractures and solution openings in limestones and dolomites

3. Saturated Thickness 500 ft (152.5 m)

4. Static Water Level

a. Depth below Surface 320 ft (97.6 m)

b. Elevation 6000 ft (1830.0 m)

c. Estimated X, Measured _____ Date _____

5. Aquifer Parameters

a. Source, Pumping Test-yes ___ no X

Description

Other Source-yes X no ___

Explanation Estimated based on general hydraulic characteristics of Eastern Assemblage materials in other areas of Nevada.

b. Transmissivity (T) 250,000 gpd/ft (3100.0 m^2/d)

c. Hydraulic Conductivity (K) 500 gpd/ft^2 (20.4 m/d)

d. Storage Coefficient (S) 5×10^{-4}

7. Possible Boundaries None

B. Water Quality

1. Total Dissolved Solids (TDS) 200-500 mg/l

2. Electrical Conductivity (EC) ______ μmhos/cm @ 25°C

3. Temperature _____ °C

4. General Water Type Calcium bicarbonate, sodium-calcium bicarbonate

5. Problem Constituents Iron and manganese may be high

6. Possible Treatment Necessary Not enough data available for evaluation

ᵀᵀI. WELL FIELD DESIGN CRITERIA

A. General

1. Number of Wells

a. Primary __2__

b. Backup __2__

c. Total Number __4__

2. Capacity __2700__ gpm (__170.4__ lps)

3. Spacing __1000__ ft (__305.0__ m)

4. Total depth __2600__ ft (__793.0__ m)

B. Well Design

1. Hole Diameter _____ in. (_______ cm)

2. Drilling Method ____

____

____

____

3. Casing Requirements

a. Surface Casing

Type ____

Diameter __________ in. (__________ cm)

Wall Thickness __________ in. (____________ cm)

Length _______ ft (__________ m)

Installation Depth from ______ ft (_______ m) to ______ ft

(_____ m) below surface

Seal ____

____

____

b. Production Casing

Type ____

Diameter ________ in. (________ cm)

Wall Thickness ________ in. (__________ cm)

Length ______ ft (_________ m)

Installation ____________________________________

____

____

____

c. Screen

Type ____

Diameter _______ in. (_______ cm)

Size of Openings ______ in. (_______ cm)

Total Length ______ ft (______ m)

Installation ____________________________________

____

____

____

4. Gravel Pack

a. Grain Size ____________________________________

____

b. Placement from _____ ft (_____ m) to ______ ft (_______ m) below surface

c. Installation ____________________________________

____

____

____

d. Seal ______________________________

____

____

____

C. Pump Design

1. Anticipated Pumping Water Level 410 ft (125.1 m) below Surface; 5910 ft (1802.6 m) Elevation

2. Head Loss due to Pump Column _____ft (_____m)

3. Total Dynamic Head _____ft (_____m)

4. Pump Requirements

a. Type ______________________________

b. Motor _____HP (_____Kw)

c. Number of Stages _____

d. Diameter of Pump Column _____in. (_____cm)

e. Pump Setting _____ft (_____m) below Surface

_____ft (_____m) Elevation

D. Pipe Line Design

1. Lift from Well Field to Mill 380 ft (115.9 m)

2. Length of Pipeline

a. Tie Line Between Wells 3000 ft (915.0 m)

b. Well Field to Mill 47100 ft (14365.5 m) or

8.9 mi (14.3 km)

3. Diameter of Pipeline

a. Tie Line _____in. (_____cm)

b. Transmission Line _____in. (_____cm)

E. Estimated Costs for Wells and Pumps

1. Well Drilling and Completion

   $_________ per well x _____ wells = $_________Total for Well Field

2. Pumps (including installation)

   $_________ per installation x _____ wells = $_________ Total for Well Field

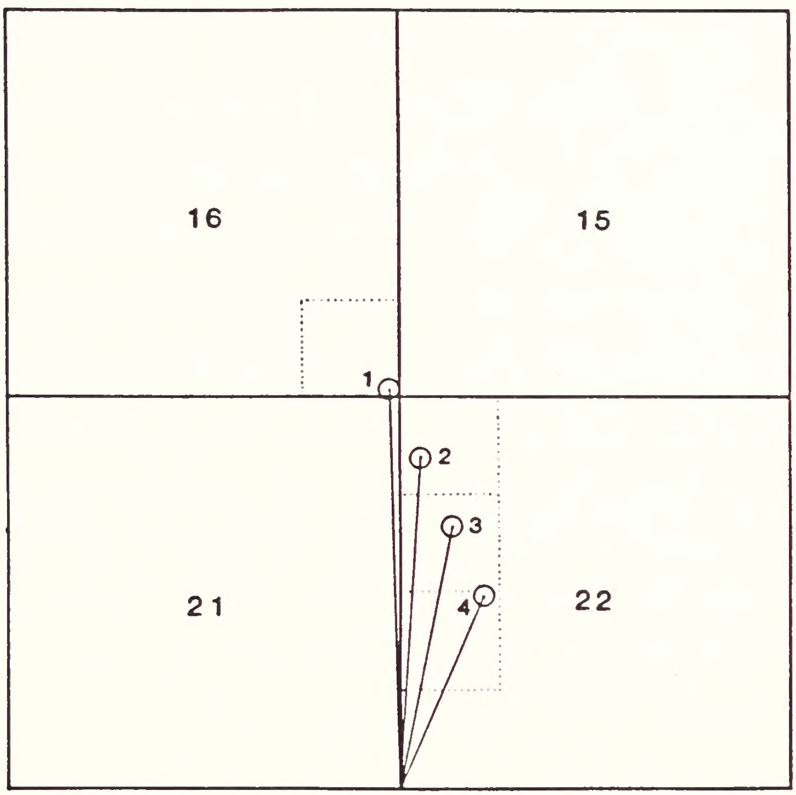
3. Total Estimate for Well Field $_________

EXXON MINERALS COMPANY

GARDEN "B" WELL FIELD
EUREKA COUNTY, NEVADA

WELL SITE	BEARING	DISTANCE, feet	(m)
1	S 1°20'W	5,359	(1634.5)
2	S 3°45'W	4,462	(1360.9)
3	S11°30'W	3,590	(1095.0)
4	S23°30'W	2,798	(853.4)

Bearing and distance is from well site to SW corner of Section 22.



T 25 N, R 51 E

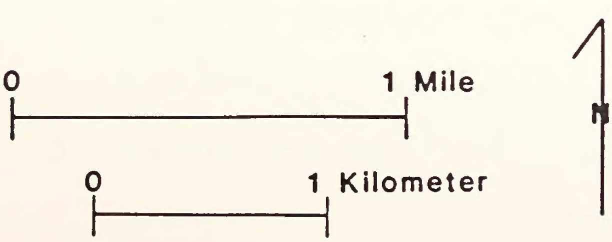


FIGURE B-8

WELL LOCATIONS

GARDEN "B" WELL FIELD

PROJECT 1298-82	REVISIONS
DATE March 1982	

Hydro-Search, Inc.
CONSULTING HYDROLOGISTS-GEOLOGISTS
Austin • Denver • Reno

EXXON MINERALS COMPANY
MT. HOPE PROJECT
PHASE I HYDROLOGY

Well Field Summary

Well Field Name Garden B

Priority Ranking

A. Well Field vs Well Field 6

B. Within Basin 1

I. WATER RIGHTS ACQUISITION

A. Basin Name Garden/Pine Valley Designated-yes ____ no X

B. Points of Diversion (Well Locations)

1. SE 1/4, SE 1/4, Sec.16, T.25N., R.51E., M.D.B. & M.
2. NW 1/4, NW 1/4, Sec.22, T.25N., R.51E., M.D.B. & M.
3. SW 1/4, NW 1/4, Sec.22, T.25N., R.51E., M.D.B. & M.
4. NW 1/4, SW 1/4, Sec.22, T.25N., R.51E., M.D.B. & M.

C. Surface Elevation (above Mean Sea Level, USGS Datum)

1. 5840 ft. (1781.2 m) Est. from Topo Map X , Surveyed ______
2. 5845 ft. (1782.7 m) Est. from Topo Map X , Surveyed ______
3. 5850 ft. (1784.3 m) Est. from Topo Map X , Surveyed ______
4. 5855 ft. (1785.8 m) Est. from Topo Map X , Surveyed ______

D. Nearest Well or Permit

1. Permit Number 15454
2. Owner Eureka Livestock Co.
3. Status of Permit-Certificated ____ Permitted Yes Pending ____
4. Flow Rate 4.0 cfs (113.3 lps)
5. Distance from Well Field 2.2 mi (3.5 km), Southeast

E. Possible Problems with Water Rights Acquisition

Although Garden/Pine Valley is undesignated, this well field is in an area of agricultural development. Some protests to water rights applications should be expected.

II. HYDROGEOLOGIC DATA

A. Primary Aquifer

1. Geologic Unit Quaternary-Tertiary alluvium
2. Aquifer Materials Sand and gravel interbedded and intermixed with silt and clay
3. Saturated Thickness 400 ft (122.0 m)
4. Static Water Level
   a. Depth below Surface 40 ft (12.2 m)
   b. Elevation 5810 ft (1772.1 m)
   c. Estimated X , Measured ____ Date ____
5. Aquifer Parameters
   a. Source, Pumping Test-yes ____ no X

      Description ____

      Other Source-yes X no ____

      Explanation Estimated based on materials in other alluvial basins in Nevada

b. Transmissivity (T) 200,000 gpd/ft (2480.0 m^2/d)

c. Hydraulic Conductivity (K) 500 gpd/ft^2 (20.4 m/d)

d. Storage Coefficient (S) 1×10^{-2}

7. Possible Boundaries None

B. Water Quality

1. Total Dissolved Solids (TDS) 200-500 mg/l
2. Electrical Conductivity (EC) ______ μmhos/cm @ 25°C
3. Temperature ______ °C
4. General Water Type Calcium bicarbonate, sodium calcium bicarbonate
5. Problem Constituents Iron and manganese may be high
6. Possible Treatment Necessary Not enough data available for evaluation

VII. WELL FIELD DESIGN CRITERIA

A. General

1. Number of Wells

a. Primary ___2___

b. Backup ___2___

c. Total Number ___4___

2. Capacity _2700___gpm (_170.4___lps)

3. Spacing _1000___ft (__305.0__m)

4. Total depth 440_____ft (134.2___m)

B. Well Design

1. Hole Diameter _____in. (______cm)

2. Drilling Method ____

____

____

____

3. Casing Requirements

a. Surface Casing

Type ____

Diameter __________in. (__________cm)

Wall Thickness __________in. (____________cm)

Length ______ft (__________m)

Installation Depth from _____ft (______m) to _____ft

(_____m) below surface

Seal ____

____

____

b. Production Casing

Type ____

Diameter _________in. (_________cm)

Wall Thickness __________in. (___________cm)

Length _______ft (__________m)

Installation ____

____

____

____

c. Screen

Type ____

Diameter _______in. (_________cm)

Size of Openings _______in. (________cm)

Total Length ______ft (_______m)

Installation ____

____

____

____

4. Gravel Pack

a. Grain Size ____

____

b. Placement from ______ft (______m) to _______ft (________m)

below surface

c. Installation ____

____

____

____

d. Seal ____

____

____

____

C. Pump Design

1. Anticipated Pumping Water Level 130 ft (39.7 m) below Surface; 5720 ft (1744.6 m) Elevation

2. Head Loss due to Pump Column _____ft (______m)

3. Total Dynamic Head _____ft (_____m)

4. Pump Requirements

a. Type ____

b. Motor ______HP (_______Kw)

c. Number of Stages ______

d. Diameter of Pump Column _____in. (_____cm)

e. Pump Setting _____ft (_____m) below Surface

_____ft (_____m) Elevation

D. Pipe Line Design

1. Lift from Well Field to Mill 860 ft (262.3 m)

2. Length of Pipeline

a. Tie Line Between Wells 3000 ft (915.0 m)

b. Well Field to Mill 102700 ft (31323.5 m) or

19.5 mi (31.4 km)

3. Diameter of Pipeline

a. Tie Line _____in. (______cm)

b. Transmission Line _____in. (______cm)

E. Estimated Costs for Wells and Pumps

1. Well Drilling and Completion

   $________ per well x ____ wells = $_________Total for Well Field

2. Pumps (including installation)

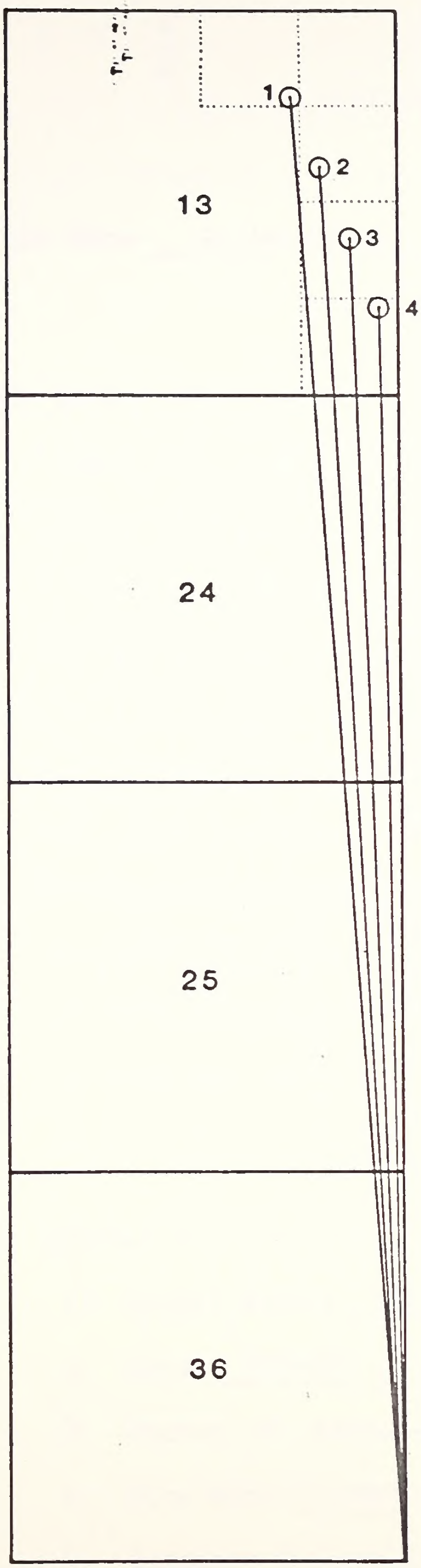
   $________ per installation x ____ wells = $_________ Total for Well Field

3. Total Estimate for Well Field $_________

EXXON MINERALS COMPANY

GARDEN "C" WELL FIELD

EUREKA COUNTY, NEVADA



T 26 N, R 50 E

WELL SITE	BEARING	DISTANCE, feet	(m)
1	S 4°10'E	20.011	(6103.4)
2	S 3°10E	18,955	(5781.3)
3	S 2°05'E	17,978	(5483.3)
4	S 0°55'E	17,002	(5185.6)

Bearing and distance is from well site to SE corner of Section 36.

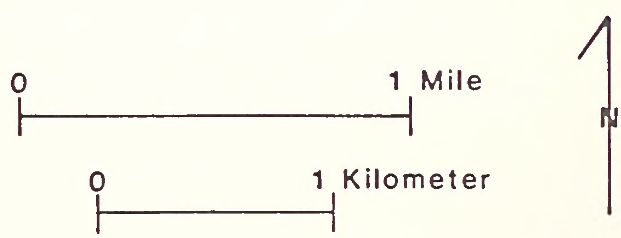


FIGURE B-9

WELL LOCATIONS

GARDEN "C" WELL FIELD

PROJECT 1298-82

DATE March 1982

REVISIONS

Hydro-Search, Inc.

CONSULTING HYDROLOGISTS-GEOLOGISTS

Austin • Denver • Reno

EXXON MINERALS COMPANY
MT. HOPE PROJECT
PHASE I HYDROLOGY

Well Field Summary

Well Field Name Garden C

Priority Ranking

A. Well Field vs Well Field 7

B. Within Basin 2

I. WATER RIGHTS ACQUISITION

A. Basin Name Garden/Pine Valley Designated-yes ____ no X

B. Points of Diversion (Well Locations)

1. NW 1/4, NE 1/4, Sec.13, T.26N., R.50E., M.D.B. & M.
2. SE 1/4, NE 1/4, Sec.13, T.26N., R.50E., M.D.B. & M.
3. NE 1/4, SE 1/4, Sec.13, T.26N., R.50E., M.D.B. & M.
4. SE 1/4, SE 1/4, Sec.13, T.26N., R.50E., M.D.B. & M.

C. Surface Elevation (above Mean Sea Level, USGS Datum)

1. 5520 ft. (1683.6 m) Est. from Topo Map X, Surveyed ____
2. 5520 ft. (1683.6 m) Est. from Topo Map X, Surveyed ____
3. 5500 ft. (1677.5 m) Est. from Topo Map X, Surveyed ____
4. 5495 ft. (1676.0 m) Est. from Topo Map X, Surveyed ____

D. Nearest Well or Permit

1. Permit Number 33294
2. Owner Unknown
3. Status of Permit-Certificated ____ Permitted Yes Pending ____
4. Flow Rate unknown cfs (____ lps)
5. Distance from Well Field 0.8 mi (1.3 km), North-northeast

E. Possible Problems with Water Rights Acquisition

Although Garden/Pine Valley is undesignated, the well field is located in an area of agricultural development. Some protest to water rights applications should be expected.

II. HYDROGEOLOGIC DATA

A. Primary Aquifer

1. Geologic Unit Quaternary-Tertiary alluvium

2. Aquifer Materials Sand and gravel interbedded and intermixed with silt and clay

3. Saturated Thickness 400 ft (122.0 m)

4. Static Water Level

a. Depth below Surface Flowing ft (______ m)

b. Elevation 5495+ ft (1676.0+m)

c. Estimated X, Measured ______ Date ______

5. Aquifer Parameters

a. Source, Pumping Test-yes ____ no X

Description ______

Other Source-yes X no ____

Explanation Estimated based on materials from other alluvial basins in Nevada

b. Transmissivity (T) 200,000 gpd/ft (2480.0 m^2/d)

c. Hydraulic Conductivity (K) 500 gpd/ft^2 (20.4 m/d)

d. Storage Coefficient (S) 1×10^{-2}

7. Possible Boundaries None

B. Water Quality

1. Total Dissolved Solids (TDS) 200-500 mg/l

2. Electrical Conductivity (EC) ______ μmhos/cm @ 25°C

3. Temperature _____ °C

4. General Water Type Calcium bicarbonate, sodium calcium bicarbonate

5. Problem Constituents Iron and manganese may be high

6. Possible Treatment Necessary Not enough data available for evaluation

II. WELL FIELD DESIGN CRITERIA

A. General

1. Number of Wells

a. Primary __2___

b. Backup __2__

c. Total Number __4__

2. Capacity 2700____gpm (_170.4___lps)

3. Spacing _1000__ft (305.0____m)

4. Total depth _400___ft (122.0___m)

B. Well Design

1. Hole Diameter _____in. (_______cm)

2. Drilling Method ____

____

____

____

3. Casing Requirements

a. Surface Casing

Type ____

Diameter __________in. (__________cm)

Wall Thickness __________in. (____________cm)

Length ______ft (__________m)

Installation Depth from ______ft (_______m) to ______ft

(_____m) below surface

Seal ____

____

____

b. Production Casing

Type ____

Diameter ________ in. (________ cm)

Wall Thickness ________ in. (__________ cm)

Length ______ ft (_________ m)

Installation ____

____

____

____

c. Screen

Type ____

Diameter ______ in. (________ cm)

Size of Openings ______ in. (_______ cm)

Total Length ______ ft (_______ m)

Installation ____

____

____

____

4. Gravel Pack

a. Grain Size ____

____

b. Placement from _____ ft (______ m) to ______ ft (_______ m) below surface

c. Installation ____

____

____

____

d. Seal ______________________________

____

____

____

C. Pump Design

1. Anticipated Pumping Water Level __90__ ft (__27.5__ m) below Surface; __5405__ ft (__1648.5__ m) Elevation

2. Head Loss due to Pump Column _____ ft (_____ m)

3. Total Dynamic Head _____ ft (_____ m)

4. Pump Requirements

a. Type ______________________________

b. Motor ______ HP (______ Kw)

c. Number of Stages ______

d. Diameter of Pump Column _____ in. (_____ cm)

e. Pump Setting _____ ft (_____ m) below Surface

_____ ft (_____ m) Elevation

D. Pipe Line Design

1. Lift from Well Field to Mill __1200__ ft (__366.0__ m)

2. Length of Pipeline

a. Tie Line Between Wells __3000__ ft (__915.0__ m)

b. Well Field to Mill __148200__ ft (__45201.0__ m) or

__28.1__ mi (__45.2__ km)

3. Diameter of Pipeline

a. Tie Line _____ in. (_____ cm)

b. Transmission Line _____ in. (_____ cm)

E. Estimated Costs for Wells and Pumps

1. Well Drilling and Completion

   $________ per well x ____ wells = $________Total for Well Field

2. Pumps (including installation)

   $________ per installation x ____ wells = $________ Total for Well Field

3. Total Estimate for Well Field $________

APPENDIX 4-C

PROJECTED DRAWDOWN FOR

POTENTIAL WELL FIELDS

PROJECTED DRAWDOWN FOR POTENTIAL WELL FIELDS

General Comments

The drawdown from each of the potential well fields was calculated for two cases representing different pumping schemes.

Case 1

This case includes 4 wells pumping 1350 gpm (85.2 lps) for 20 years. These conditions were selected to simulate drawdowns over the projected life of the mine.

Case 2

This case includes 2 wells pumping 2700 gpm (170.4 lps) for 6 months. These conditions were selected to represent the "worst case" in any given year from producing 5400 gpm (340.7 lps) any two of the four wells from each well field.

Aquifer constants (i.e., transmissivity and storage coefficient) used in the calculations were those described in Section 5.3.1. These values are not based on any reliable aquifer test data and were estimated by adapting transmissivities and storage coefficients from other areas of similar geology to the anticipated conditions at the proposed well fields. As such, the resultant calculations should only be used as approximations for planning purposes. Detailed investigation of

drawdowns for the selected well fields by aquifer tests should be included in a program of future hydrologic work for the project.

The calculated drawdowns at various distances from the well fields are shown on Figures D-1 through D-6. Some of the figures (i.e., D-3, D-5, and D-6) represent drawdown projections at two well fields, because aquifer characteristics at some of the well fields were similar to those estimated at other well fields.

Calculator Program

A program was devised for a Hewlett Packard HP-29C programmable calculator which projects the drawdown at any given point away from a pumping well field. The program permits placement of wells in any desired arrangement on the basis of a Cartesian Coordinate System. For this study, all of the well fields are comprised of a line of wells with 1000 feet (305.0 m) spacings. The program allows for simulation of discharge boundary conditions by placing an image well field at an appropriate position away from the well field. Image wells were used for evaluating a possible boundary at Kobeh "A" (Figure D-1).

Drawdown Equation

The drawdown from the proposed well fields is calculated through the use of a standard formula for a single well adopted to a multiple well arrangement. For unsteady radial flow to a single well pumping at a constant rate, the drawdown at any distance and at any time since

pumping started is given by Theis (1935) for dimensionally consistent units:

$$s = \frac{Q}{4\pi T} \quad W(u),$$

$$u = \frac{r^2 S}{4Tt} \quad \text{where}$$

s = drawdown

Q = discharge

T = transmissivity

r = distance from discharging well

S = storage coefficient

t = time since pumping started.

W(u) is called the well function of u, and is an improper integral which has an approximate solution in the following power series:

$$W(u) = -.5772 - \ln u + \frac{u-u^2}{2\cdot 2!} + \frac{u^3}{3\cdot 3!} + \ . \ . \ . + \frac{(-1)^{k+1}u^k}{k\cdot k!}$$

Tables exist for corresponding values of u and W(u). However, the power series can be evaluated rapidly with a programmable calculator or a computer.

The formula can be extended to a field of wells, because the principle of superposition applies. That is, the drawdown at a given point in the field is the sum of the drawdowns caused by each pumping well.

Assumptions

The basic radial flow formula used for the drawdown calculations is derived on the basis of numerous idealized assumptions.

For the drawdown projections calculated herein, the following conditions were assumed:

1. The aquifer is infinite, homogeneous, and confined.
2. Drawdown is accompanied by instantaneous release of water from storage.
3. There is no recharge to the aquifer during the period that the wells are pumping and the aquifer is receiving no leakance from the confining aquitard.
4. The wells start pumping simultaneously and the pumping rate for all wells is equal.

The first and second of the above assumptions must be carefully considered when evaluating an unconfined aquifer (such is the case in several of the proposed well fields) because: 1) the saturated thickness changes as pumping progresses, and 2) water is released from storage by gravity drainage which does not represent an instantaneous release process. Jacob (1950) has shown that reduction in saturated thickness less than ten percent does not significantly affect the calculations. However, calculated drawdowns at the well fields exhibiting unconfined conditions indicated a reduction in the saturated thickness of greater than 10 percent. The resultant drawdowns would,

therefore, be underestimated. Because the calculations assume no recharge, the effects of recharge to the aquifer would tend to negate this underestimation. In any case, the projected drawdowns for the well fields must only be considered crude approximations until sufficient data are obtained to confirm the hydrogeologic conditions at the well fields and reliable aquifer constants, based on aquifer tests, are obtained for refinement of the calculations.

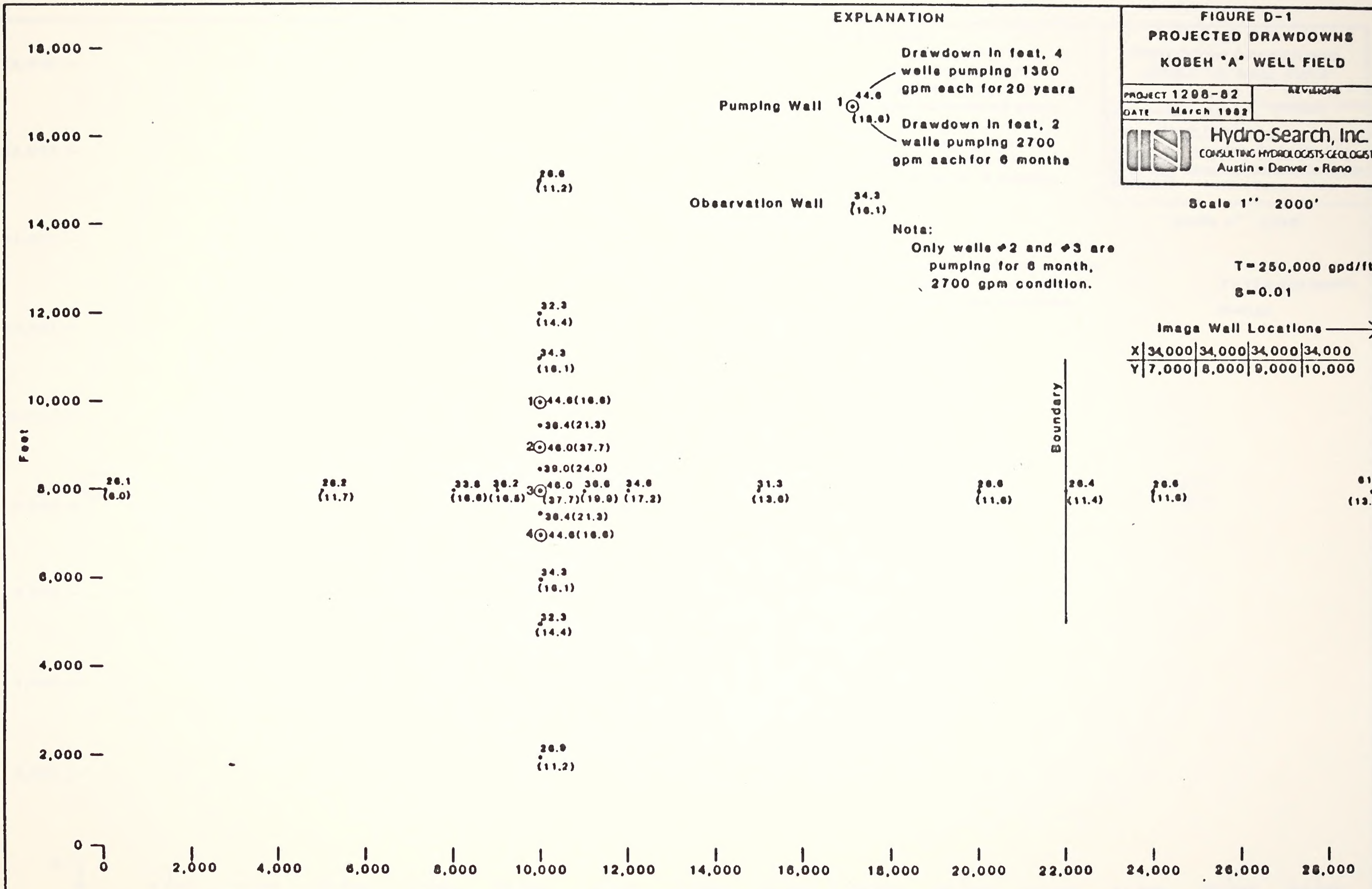


FIGURE D-1
PROJECTED DRAWDOWNS
KOBEH "A" WELL FIELD
PROJECT 1298-82
DATE March 1982
REVISIONS
Hydro-Search, Inc.
CONSULTING HYDROLOGISTS-GEOLOGISTS
Austin • Denver • Reno
Scale 1'' 2000'
T=250,000 gpd/ft
S=0.01
Image Well Locations
X 34,000 34,000 34,000 34,000
Y 7,000 8,000 9,000 10,000
EXPLANATION
Pumping Well
Drawdown in feet, 4 wells pumping 1350 gpm each for 20 years
Drawdown in feet, 2 wells pumping 2700 gpm each for 6 months
Observation Well
Note:
Only wells #2 and #3 are pumping for 6 month, 2700 gpm condition.
Boundary
Feet
Feet

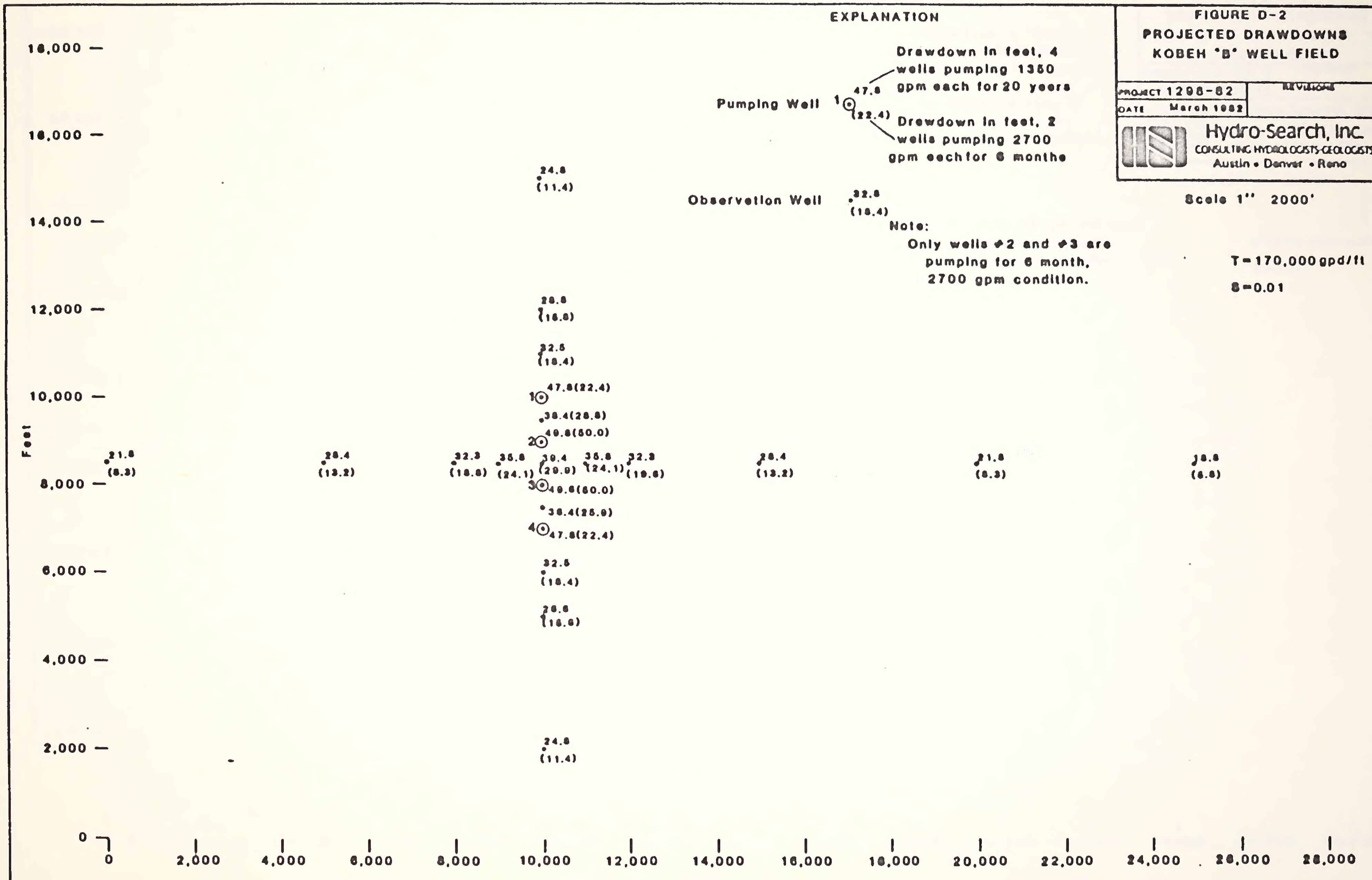


FIGURE D-2
PROJECTED DRAWDOWNS
KOBEH "B" WELL FIELD
PROJECT 1298-82
DATE March 1982
REVISIONS
Hydro-Search, Inc.
CONSULTING HYDROLOGISTS-GEOLOGISTS
Austin • Denver • Reno
Scale 1" 2000'
T=170,000 gpd/ft
S=0.01
EXPLANATION
Pumping Well
47.8
(22.4)
Drawdown in feet, 4 wells pumping 1350 gpm each for 20 years
Drawdown in feet, 2 wells pumping 2700 gpm each for 6 months
Observation Well
32.8
(18.4)
Note:
Only wells #2 and #3 are pumping for 6 month, 2700 gpm condition.
Feet
Feet
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
22,000
24,000
26,000
28,000
47.8(22.4)
38.4(28.8)
49.8(50.0)
49.8(50.0)
38.4(28.9)
47.8(22.4)

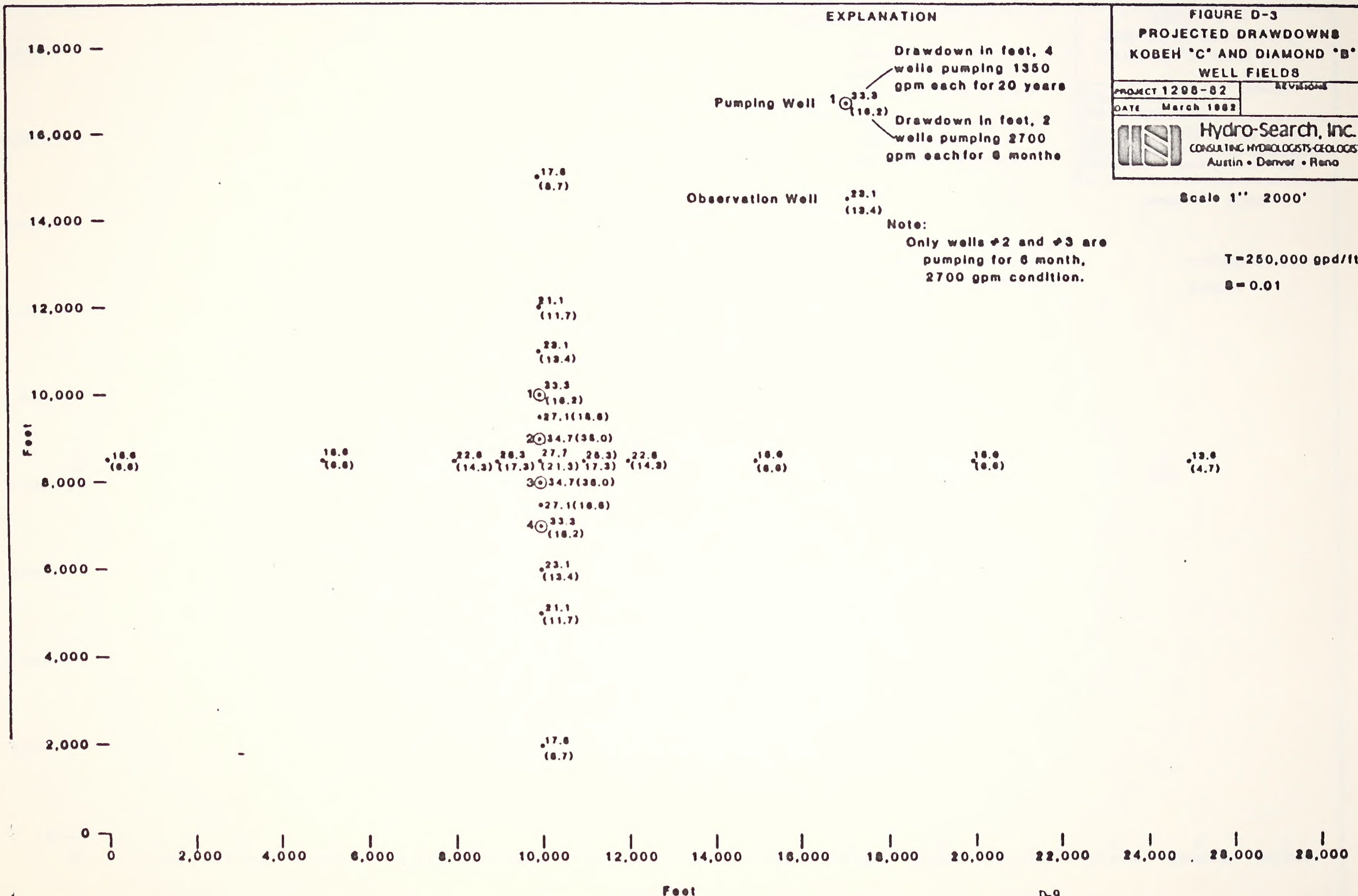


FIGURE D-3
PROJECTED DRAWDOWNS
KOBEH "C" AND DIAMOND "B"
WELL FIELDS

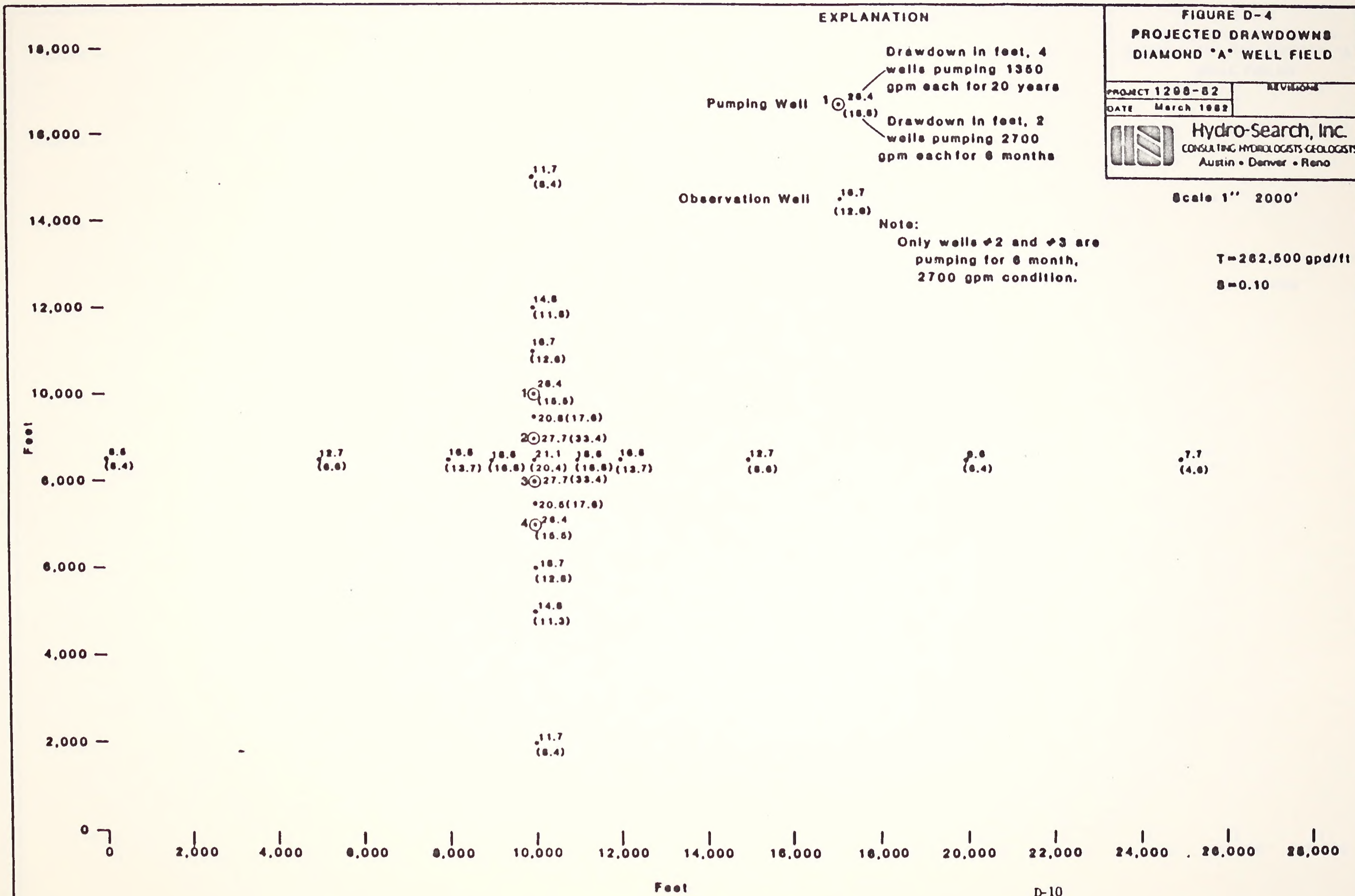
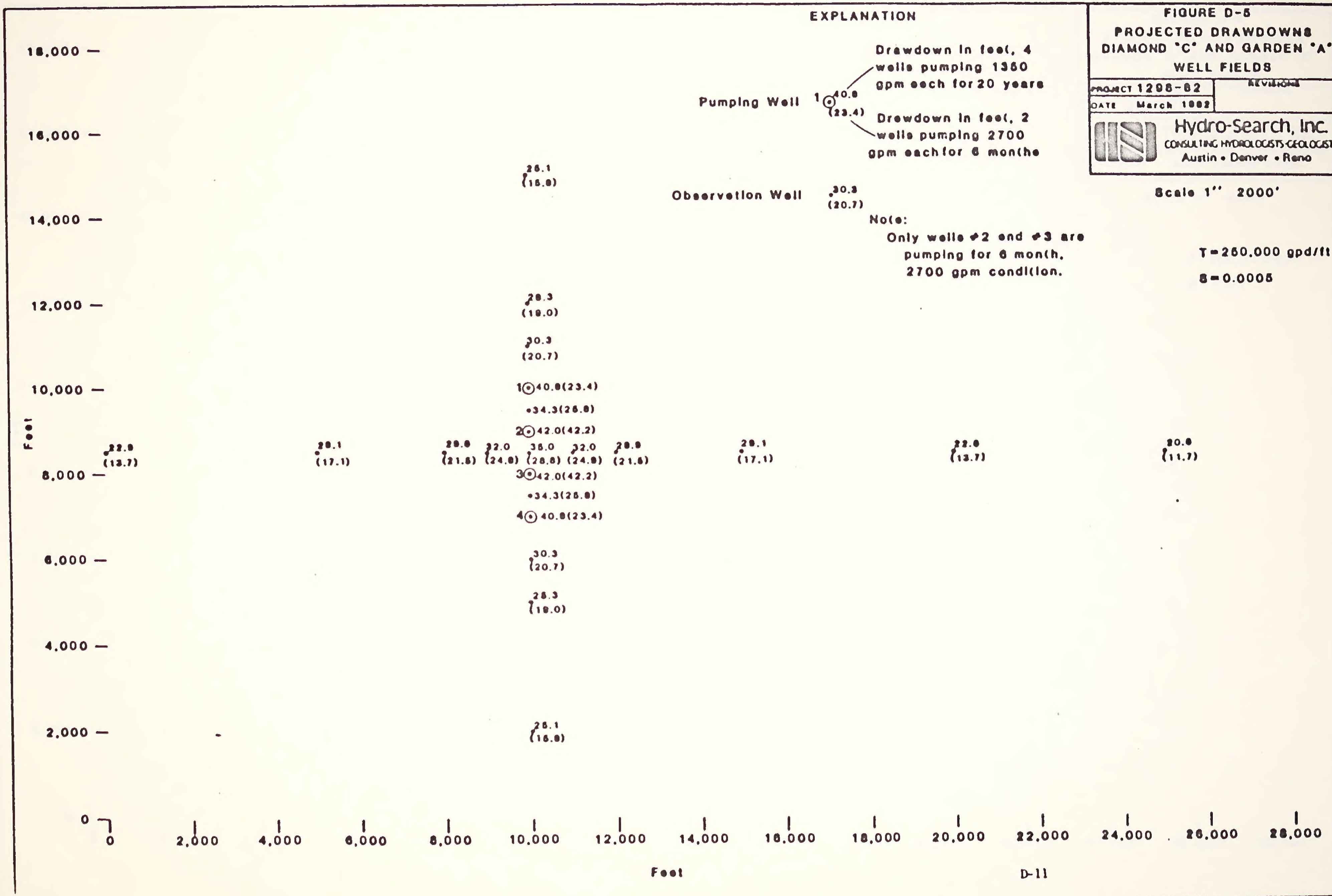


FIGURE D-4
PROJECTED DRAWDOWNS
DIAMOND "A" WELL FIELD
PROJECT 1298-82
DATE March 1982
REVISIONS
Hydro-Search, Inc.
CONSULTING HYDROLOGISTS GEOLOGISTS
Austin • Denver • Reno
Scale 1'' 2000'
T=262,500 gpd/ft
S=0.10
EXPLANATION
Pumping Well
Drawdown in feet, 4 wells pumping 1350 gpm each for 20 years
Drawdown in feet, 2 wells pumping 2700 gpm each for 6 months
Observation Well
Note:
Only wells #2 and #3 are pumping for 6 month, 2700 gpm condition.
Feet
Feet
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
22,000
24,000
26,000
28,000


EXPLANATION
Pumping Well
1 40.8 (23.4)
Drawdown in feet, 4 wells pumping 1350 gpm each for 20 years
Drawdown in feet, 2 wells pumping 2700 gpm each for 6 months
Observation Well
30.3 (20.7)
Note:
Only wells #2 and #3 are pumping for 6 month, 2700 gpm condition.
FIGURE D-5
PROJECTED DRAWDOWNS
DIAMOND "C" AND GARDEN "A" WELL FIELDS
PROJECT 1298-82
DATE March 1982
REVISIONS
Hydro-Search, Inc.
CONSULTING HYDROLOGISTS-GEOLOGISTS
Austin • Denver • Reno
Scale 1" 2000'
T=250,000 gpd/ft
S=0.0005
Feet
Feet
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
22,000
24,000
26,000
28,000
25.1 (15.8)
28.3 (19.0)
30.3 (20.7)
1 40.8(23.4)
34.3(25.8)
2 42.0(42.2)
22.8 (13.7)
28.1 (17.1)
28.8 (21.5)
32.0 (24.8)
35.0 (28.8)
32.0 (24.8)
28.8 (21.5)
28.1 (17.1)
22.8 (13.7)
20.8 (11.7)
3 42.0(42.2)
34.3(25.8)
4 40.8(23.4)
30.3 (20.7)
28.3 (19.0)
25.1 (15.8)

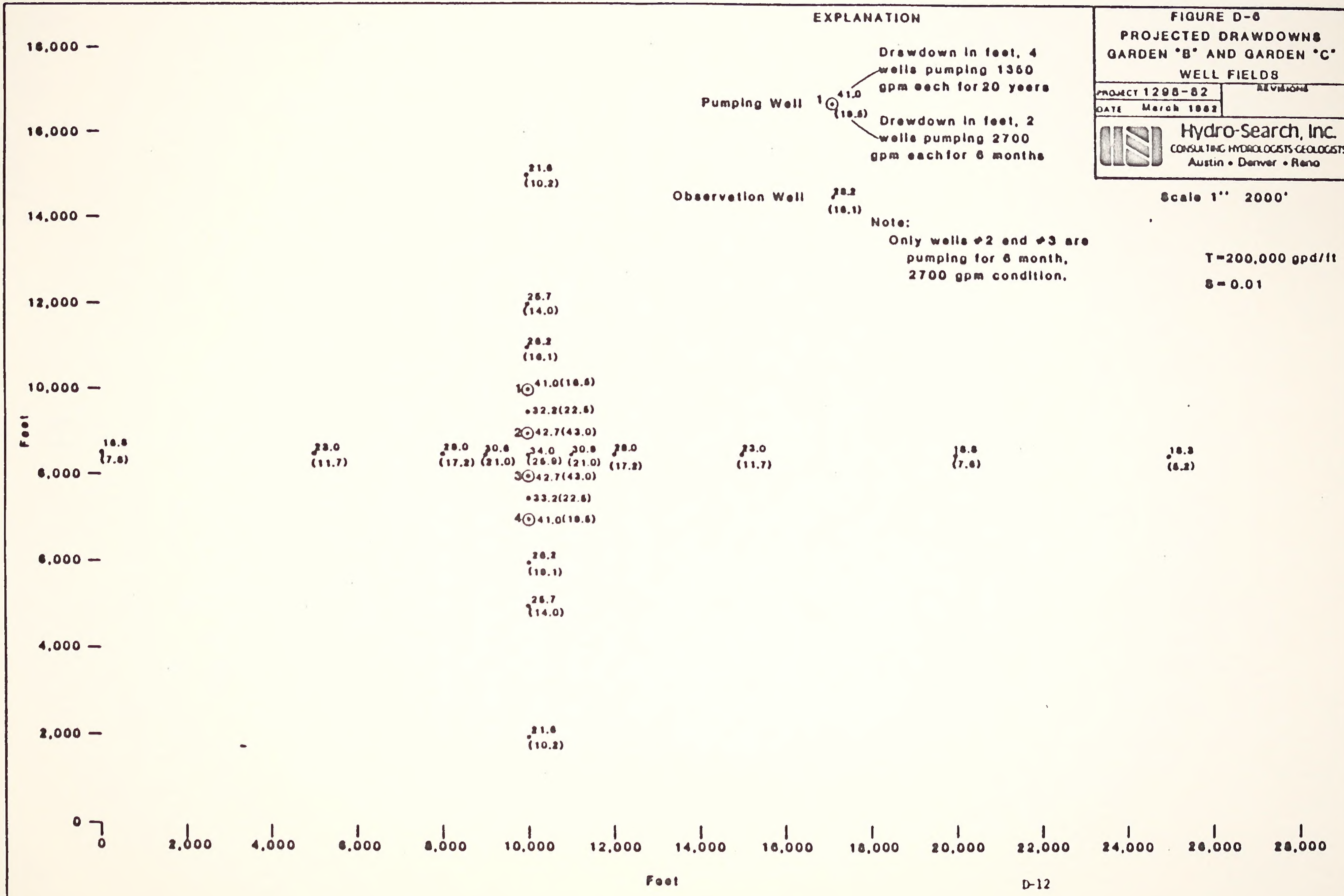


FIGURE D-6
PROJECTED DRAWDOWNS
GARDEN "B" AND GARDEN "C"
WELL FIELDS
PROJECT 1298-82
DATE March 1982
REVISIONS
Hydro-Search, Inc.
CONSULTING HYDROLOGISTS-GEOLOGISTS
Austin • Denver • Reno
Scale 1" 2000'
T=200,000 gpd/ft
S=0.01
EXPLANATION
Pumping Well
1
41.0
(19.6)
Drawdown in feet, 4 wells pumping 1350 gpm each for 20 years
Drawdown in feet, 2 wells pumping 2700 gpm each for 6 months
Observation Well
28.2
(16.1)
Note:
Only wells #2 and #3 are pumping for 6 month, 2700 gpm condition.
21.6
(10.2)
25.7
(14.0)
28.2
(16.1)
1 41.0(18.6)
32.2(22.6)
2 42.7(43.0)
18.8
(7.6)
23.0
(11.7)
28.0
(17.2)
30.6
(21.0)
34.0
(26.9)
30.8
(21.0)
28.0
(17.2)
23.0
(11.7)
18.8
(7.6)
18.3
(6.2)
3 42.7(43.0)
33.2(22.6)
4 41.0(18.6)
28.2
(16.1)
25.7
(14.0)
21.6
(10.2)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Feet
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
22,000
24,000
26,000
28,000
Feet

APPENDIX 4-D

WELL FIELD RANKING

SYSTEM

WELL FIELD RANKING SYSTEM

A subjective ranking system was devised to rate the order of priority for further development work in the well fields. The following evaluation criteria were utilized.

<u>EVALUATION CRITERIA</u>

	Weighting Factor
1. <u>Certainty of Supply</u> - Rating 5 for the most certain to 1 for the least certain. Takes into account data from wells in the area, characteristics of the basin, hydrogeology and adequacy and distribution of available data.	5
2. <u>Water Rights Acquisition</u> - Rating of 5 for the least problems in an undesignated basin to 1 for the most problems in a designated basin. Takes into account present land use (type of agriculture, etc.) ownership of lands (public, private) and draft on the local aquifers.	4
3. <u>Capital Costs</u> - Broken down separately for 1) wells and pumps, and 2) pipeline.	
<u>Wells and Pumps</u> - Rating of 5 for least expensive and 1 for most expensive costs for the total well field. Takes into account the depths of the wells and the anticipated degree	4

Weighting Factor

of difficulty associated with well construction based on anticipated geologic conditions.

Pipeline - Rating of 5 for least expensive to 1 for most expensive costs for both tie-line and transmission pipelines. Takes into account length of pipeline and anticipated construction conditions. 4

4. Operation and Maintenance Costs - Rating of 5 for least expensive to 1 for most expensive. Takes into account length of pipeline, difficulty of terrain, number of components in system (wells, pumps, lift stations, etc.), and amount of power required to pump water to point of use. 3

WEIGHTING FACTOR

Each of the above criteria are assigned a weighting factor on the basis of its relative importance in the ranking process. The weighting factors range from 5 indicating most important to 1 indicating least importance.

RANKING FORMULA

Each well field is assigned a value for each of the evaluation criteria listed above. This value was multiplied by the corresponding weighting

factor for each criterion and the total sum of the resultant products was the raw score for the individual well field. The highest possible score for any one field is 100. The well fields were then arranged with highest total score being priority one and the remaining well fields ranked consecutively behind the first. The well fields were also ranked according to priority in each hydrographic basin. The hydrographic basins were also ranked against one another on the basis of these results. The scores and results are shown on Table E-1.

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Table E-1. Summary of Well Field Ranking System.

Basin	Well Field	Certainty of Supply			Water Rights Acquisition			Capital Costs: Wells & Pumps			Capital Costs: Pipeline			Operation and Maintenance Costs			Total Score	Priority Ranking		
		Value	WF	Score	Value	WF	Score	Value	WF	Score	Value	WF	Score	Value	WF	Score		Overall	Within Basin	Basin
Kobeh Valley	A	3	5	15	5	4	20	3	4	12	4	4	16	4	3	12	75	3	2	
	B	5	5	25	4	4	16	3	4	12	3	4	12	3	3	9	74	4	3	1
	C	4	5	20	5	4	20	3	4	12	4	4	16	4	3	12	80	1	1	
Diamond Valley	A	5	5	25	1	4	4	5	4	20	3	4	12	4	3	12	73	5	2	
	B	5	5	25	2	4	8	3	4	12	5	4	20	4	3	12	77	2	1	2
	C	2	5	10	5	4	20	1	4	4	5	4	20	4	3	12	66	8	3	
Garden/Pine Valley	A	2	5	10	5	4	20	1	4	4	4	4	16	4	3	12	62	9	3	
	B	5	5	25	4	4	16	5	4	20	1	4	4	1	3	3	68	6	1	3
	C	5	5	25	4	4	16	5	4	20	1	4	4	1	3	3	68	7	2	

Note: WF means weighting factor.

APPENDIX 4-E

EXPLORATORY DRILLING AND

PUMPING TEST PROGRAMS

5.0 EXPLORATORY DRILLING PROGRAM

5.1 KOBEH "C" EXPLORATION WELL #1 (KCE #1)

Exploration drilling in Kobeh Valley began on September 11, 1982 at the Kobeh "C" location. The first exploration hole is located 50 feet (15.3 m) north of the northernmost point of diversion at "C" and under water rights permit application #44436 in the SE 1/4, SE 1/4, Section 24, T.21N., R.51E (Figure 2). Geological, geophysical, and well construction data are shown on Plate III and Figure B-1 (Appendix B). KCE #1 is 8.75 inches (22.2 cm) in diameter and completed at a total depth of 628 feet (191.5 m). Geologic materials encountered during drilling consist of variously sorted and stratified layers clay, sand, and gravel from 0-605 feet (0-184.5 m), and siliceous bedrock from 605-628 feet (184.5-191.5 m). The depth to water from the top of the casing is 81.8 feet (25.0 m). The well is cased to 628 feet (191.5 m) with 6 5/8-inch (16.8 cm) O.D. x .188-inch (.48 cm) wall, blank and single standard perforated steel casing, and nominal 6-inch (15.2 cm), 100-slot Johnson low carbon steel screen (Figure B-1, Appendix B) and gravel packed with 1/4 x 3/8-inch (.64 x .95 cm), rounded, washed, shale- and limestone-free gravel. Air lift development pumping of KCE #1 resulted in approximately 75 gpm (4.7 lps) from 620 feet (189.1 m). The rate of water production was limited by the diameter of the drill string and by the capacity of the compressor. An air lift pump test was not run because significant drawdown could not be achieved in the well.

Geologic materials intersected at KCE #1 are favorable for the development of

a significant ground-water supply. However, due to the limited thickness of saturated alluvium (525 feet, 160.1 m), the decision was made to locate the next exploration well two miles (3.22 km) to the south in an effort to intersect a thicker section of alluvial material.

5.2 DIAMOND "C" GULF HOLE

The investigation of the Gulf exploration hole began on September 22, 1982. Six-inch (15.2 cm) I.D. casing was present at the surface and a fluid level was measured at 46.41 feet (14.16 m) from the top of the casing. The hole was entered with a 5 5/8-inch (14.3 cm) tri-cone bit and 4 1/2-inch (11.43 cm) O.D. drill pipe. A blockage was encountered at 180 feet (54.9 m) which continued intermittently down to approximately 270 feet (82.4 m). The air compressor on the rig was used to clear the hole of cuttings between 180 feet (54.9 m) and 270 feet (82.4 m). Cuttings consisted of rhyolite with large quartz phenocrysts and black shale. The rhyolite cuttings indicate that a portion of the material in the hole has caved from between the 90-foot (27.5 m) and 140-foot (42.7 m) levels. The original geologic log indicates that rhyolite occurs only within this interval. Airlifting in this portion of the hole resulted in an initial slug of water which quickly reduced to a slight mist.

Drilling below the 270-foot (82.4 m) level was more difficult and foam was used to clear the hole. Water airlifted from below the 270-foot (82.4 m) level ranged from about 40 to 75 gpm (2.5 to 4.7 lps). Intermittent blockages again occurred below 290 feet (88.5 m) to 590 feet (180.0 m). The

blockages were composed of shale and rhyolite with shale predominating at depth. At the 590-foot (180.0 m) level the torque on the drill pipe reached its maximum limits and the driller informed HSI that the drilling tools could be lost if drilling continued. The tools were pulled up to 510 feet (155.6 m) and the hole was airlifted without foam to clean out the hole. At that time Exxon decided to attempt to drill deeper with a bentonite mud, until such time as the geophysical logging rig on site would start standby charges (10 hours). The rig was being prepared to switch to a mud system when a hydraulic hose burst and shut drilling operations down for about 5 hours. Water level after five hours of recovery was measured at 97.5 feet (29.7 m) from top of casing.

An obstruction was encountered at the 570-foot (173.9 m) level upon resumption of drilling with mud. This obstruction was catching the bit and causing excessive torque. The hole was circulated to clear out any remaining cuttings and then logged.

The first geophysical tool used was a caliper probe which could only be lowered to 270 feet (82.4 m). The caliper survey indicated casing down to approximately 160 feet (48.8 m). The survey also indicated unstable hole conditions below the casing and possible areas of casing that had been shot off or dynamited. Additional evidence of blasting, such as pieces of wire, were seen in the airlifted returns.

A second attempt was made to drill down below any obstruction and run natural gamma and neutron logs on the hole. This was unsuccessful because an

obstruction at 290 feet (88.5 m) could not be cleared. At that point, the decision was made that further attempts to log the hole could result in loss of geophysical tools. The drill rig was mobilized to Kobeh Valley to start on the second exploration hole.

5.3 KOBEH "C" EXPLORATION WELL #2 (KCE #2)

Kobeh "C" exploration Well #2 (KCE #2) was started on September 24, 1982. The location is approximately 2 miles (3.22 km) south of KCE #1 in the SW 1/4, SE 1/4, Section 36, T.21N., R.51E (Figure 2). Geological, geophysical, and well construction data are shown on Plate IV and Figure B-2. The borehole diameter is 8.5 inches (21.6 cm) to a total depth of 1100 feet (335.5 m). The casing is 6 5/8-inch (16.8 cm) O.D. x .188-inch (.48 cm) wall, blank and single standard perforated steel casing and nominal 6-inch (15.2 cm), 100-slot Johnson low carbon steel screen (Figure B-2, Appendix B). A gravel pack extends from 50 to 1100 feet (15.3 to 335.5 m) and consists of 1/4 x 3/8-inch (.64 x .95 cm) rounded, washed, shale- and limestone-free gravel. A cement seal extends from 0 to 50 feet (0 to 15.3 m).

The bedrock material intersected at KCE #1 was not intersected at KCE #2, however, a very hard zone was encountered between 987 and 991 feet (301.0 and 302.3 m). The penetration rate above 987 feet (301.0 m) usually ranged from between 40 and 50 feet (12.2 and 15.3 m) per hour. Below 991 feet (302.3 m), the penetration rate dropped to between 20 and 30 feet (6.1 and 9.2 m) per hour. This reduced rate, however, was still much higher than that seen during the drilling of the bedrock material in KCE #1 (9 feet (2.7 m) per

hour) and the cuttings indicated the hole was still in alluvium. The alluvial materials in KCE #2 were very similar to those found in KCE #1 except that less clay was present in KCE #2.

Air lift development pumping of KCE #2 resulted in approximately 75 gpm (4.7 lps) from 300 feet (91.5 m). Drawdown in the well after 1.5 hours of pumping was 25 feet (7.6 m).

5.4 KOBEH "C" EXPLORATION WELL #3 (KCE #3)

Kobeh "C" exploration well #3 (KCE #3) was started on October 9, 1982 and is located in the NW 1/4, N/W 1/4, Section 26, T.21N., R.51E (Figure 2). Geological, geophysical, and well construction data are shown on Plate V and Figure B-3. The borehole diameter is 8.5 inches (21.6 cm) to a total depth of 640 feet (195.2 m). The casing is 6 5/8-inch (16.8 cm) O.D. x .188-inch (.48 cm) wall, blank and single standard perforated steel casing and nominal 6-inch (15.2 cm), 100-slot Johnson low carbon steel screen (Figure B-3, Appendix B). A gravel pack extends from 50 to 640 feet (15.3 to 195.2 m) and consists of 1/4 x 3/8-inch (.64 x .95 cm) rounded, washed, shale- and limestone-free gravel. A cement seal extends from 0 to 50 feet (0 to 15.3 m).

Geologic materials intersected at KCE #3 include both the alluvium and siliceous bedrock. Alluvium extends from the surface to 500 feet (152.5 m) and bedrock from 500 feet (152.5 m) to total depth. These materials are very similar to those found in KCE #1.

Air lift development pumping of KCE #3 resulted in approximately 75 gpm (4.7 lps) from 620 feet (189.1 m). 200 pounds (90.8 kg) of dispersant were used during the gravel packing and air lift development pumping. The well was then injected with a solution containing 400 pounds (181.6 kg) of Cotey Dry Acid. The acid solution was left in the well be to pumped out during development pumping prior to test pumping of the test well.

5.5 KOBEH "C" EXPLORATION HOLE #4 (KCE #4)

Kobeh "C" exploration hole #4 (KCE #4) was started on October 25, 1982 and is located in the SW 1/4, NW 1/4, Section 25, T.21N., R.51E. (Figure 2). The borehole diameter is 5 5/8 inches (14.3 cm) to a total depth of 540 feet (164.7 m). The casing is 3-inch (7.6 cm) I.D. fiberglass pipe with two, 1/4-inch (.64 cm) circular perforations per foot (Plate VI and Figure B-4, Appendix B).

Geologic materials intersected at KCE #4 based on drill cuttings are alluvium as seen in the previous holes (Plate VI). This hole was drilled with a polymer mud to aid in its development and also to evaluate this method of drilling in the geologic materials found in the vicinity.

5.6 KOBEH "C" EXPLORATION HOLE #5 (KCE #5)

Kobeh "C" exploration hole #5 (KCE #5) was started on October 27, 1982 and is located in the NW 1/4, SE 1/4, Section 36, T.21N., R.51E. (Figure 2). The borehole diameter is 8.5 inches (21.6 cm) to a total depth of 500 feet (152.5 m). This hole is cased with blank and perforated 3-inch (7.6 cm) fiberglass

pipe to 485 feet (147.9 m) (Plate VI and Figure B-5, Appendix B).

Geologic materials found in this hole were similar to those found in KCE #2, i.e. relatively clean gravel and sand with minor amounts of silt and clay (Plate VI).

5.7 KOBEH "C" EXPLORATION HOLE #6 (KCE #6)

Kobeh "C" exploration hole #6 (KCE #6) was started on November 3, 1982 and is located in the SW 1/4, SE 1/4, Section 36, T.21N., R.51E. (Figure 2). The borehole diameter is 8.5 inches (21.6 cm) to a total depth of 500 feet (152.5 m). This hole was cased with 3-inch (7.6 cm) blank and circular perforated fiberglass pipe (Plate VI and Figure B-6, Appendix B) to a total depth of 500 feet (152.5 m).

An HSI field representative was not present during drilling, but geologic materials were reported by the driller as sand and gravel with minor clay and silt to total depth.

5.8 ANALYSIS OF DATA FROM EXPLORATORY DRILLING PROGRAM

Analysis of the geological, geophysical, and drilling data obtained during the exploratory drilling program indicates the following:

1. Alluvial deposits in the vicinity of Kobeh "C" consist of variously sorted and stratified layers of clay, silt, sand, and gravel.
2. Geophysical logs show sufficient coarse-grained layers in the alluvium to allow significant water production to a properly constructed well.

3. The alluvial aquifer is approximately 600 feet (183 m) thick in the vicinity of KCE #1 on the north and increases in thickness to greater than 1100 feet (335.5 m) in the vicinity of KCE #2 on the south.
4. Saturated thickness of the aquifer increases from about 520 feet (158.6 m) at KCE #1 to greater than 1060 feet (323.3 m) at KCE #2.
5. Drill cuttings show an increase in coarse-grained material at KCE #2 relative to KCE #1 and KCE #3.

The location for the construction of the test well (KCT #1) was selected on the basis of these data. KCT #1 is located 50 feet (15.3 m) north of KCE #2 (Figure 2).

6.0 PUMPING TEST PROGRAM

6.1 KOBEH "C" TEST WELL #1 (KCT #1)

Kobeh "C" test well #1 (KCT #1) was started on November 9, 1982 and is located 50 feet (15.3 m) north of KCE #2 and is in line with KCE #1, 2, 5, and 6 (Figure 2). The location is in the SW 1/4, SE 1/4, Section 36, T.21N., R.51E. The borehole diameter is 24 inches (61 cm) to a total depth of 845 feet (257.7 m). This well is cased with 16-inch (40.6 cm), blank, single, and double perforated casing and 100-slot Johnson low carbon steel screen (Plate VII and Figure B-7, Appendix B). Gravel pack consists of 1/8 x 3/8-inch (.64 x .95 cm), rounded, washed, shale and limestone-free gravel from 50 (15.3 m) to 845 feet (257.7 m). The annulus between the casing and hole wall is sealed with cement from 50 feet (15.3 m) to the ground surface.

The test well location was chosen on the basis of the previous exploration hole results. Geologic materials were very similar in all of the exploration holes; however, the thickness of saturated alluvium at KCE #2, in excess of 1000 feet (305 m), was the major consideration in selecting the location for KCT #1. This location is probably far enough south to allow for construction of a wellfield to the north and/or west without intersecting bedrock at too shallow a depth.

The hole was drilled in three passes. The pilot hole (12-inch (30.5 cm)) was started with an 8 1/2-inch (21.6 cm) tri-cone and 12-inch (30.5 cm) reaming bit combination. The pilot-reaming bit combination failed at about 500 feet (152.5 m) and was replaced with a 12 1/4-inch (31.1 cm) long-tooth tricone

bit. The 12 1/4-inch (31.1 cm) tricone bit was used to complete the pilot hole to total depth. The hole was terminated at 845 feet (257.7 m), well above the projected depth of 1100 feet (335.5 m), because a sufficient length of 4 1/2-inch (11.4 cm) drill steel was not available on site. The use of available, smaller diameter drill pipe could have caused failure of the drill string, and the decision was made to terminate drilling. As a result, some of the better potential water-producing zones as shown on the geophysical log for KCE #2 (Plate IV) occurring from 900 to 1050 feet (274.5 to 320.3 m) were not penetrated by this well.

Downhole geophysical logs were run upon completion of the pilot hole on November 15, 1982 (Plate VII). Evaluation of the geologic and geophysical logs confirmed earlier exploration drilling results indicating a multilayered, alluvial aquifer system containing numerous layers of relatively coarse grained (sand and gravel) material. The saturated thickness of the aquifer penetrated in KCT #1 was approximately 800 feet (244 m).

Reaming of the pilot hole started on November 16, 1982 and ended on December 19, 1982. This was completed in two passes. The first was 17 inches (43.2 cm) and the final pass was 24 inches (61 cm). Reaming operations were delayed by numerous breakdowns in the drill rig's hydraulic fluid system, and problems resulting from poorly remanufactured drill bits. These delays required additional bentonite and other drilling additives to be incorporated into the drilling fluid system at each shutdown.

Total drilling additives used during the drilling and reaming of KCT #1, as reported by Exxon Minerals Company personnel, include: 175 bags of bentonite (8750 lbs (3973 kg)), 16 bags of CMC gel (800 lbs (363 kg)), 40 bags of lignite (2000 lbs (908 kg)), 1 bag of soda ash (50 lbs (23 kg)), and 5 gallons (19 litres) of drilling detergent.

Casing of KCT #1 took place during December 20-23, 1982 (Plate VII and Appendix B). After casing operations were completed, the well was left filled with drilling fluid and without installation of a gravel pack until after the holiday break. The gravel pack was installed on December 30, 1982. A total of fifty cubic yards (38.2 m^3) of gravel were installed from 50 to 845 feet (15.3 to 257.7 m). The gravel was installed while thinning the drilling mud with water and 200 lbs (91 kg) of sodium acid pyrophosphate. A total of 51 days elapsed between the start of drilling to the beginning of development work.

Development surging and jetting with the drill rig began on December 30, 1982. This was done with a combination tool that acted as both a swab and jetting tool. This tool was used in combination with 600 lbs (272 kg) of sodium acid pyrophosphate. The development tool was placed at the bottom of the casing prior to gravel packing and was run the full length of the perforated portion of the well (60 to 800 feet (18 to 244 m)) three times. Each of the three passes was accomplished by swabbing and jetting with each length of drill pipe. Development work with the drill rig was completed on December 31, 1982.

Development pumping with the pump supplied by William Cooper and Sons Drilling, Inc. began on January 15, 1983. This pump was set at 250 feet (76.3 m). According to Cooper's contract, this pump was to be capable of producing approximately 1500 gpm (95 lps) from 250 feet (76.3 m). After the initial surge pumping, excessive drawdown caused the pump to break suction at 300 gpm (19 lps). Development pumping was terminated January 16, 1983, pending additional physical and chemical development and mobilization of a pumping contractor with more suitable pumping equipment that could be installed at greater depth and which could produce a discharge rate well in excess of 300 gpm (19 lps) at a higher lift.

A well development program supervised by Exxon Minerals Company personnel, including physical and chemical techniques, was started mid-April. This program included treatment of KCT #1 with 4000 lbs (1816 kg) of sodium hexametaphosphate and 4500 lbs (2043 kg) of Cotey Dry Acid, a mud dispersant. This program included bailing, surging, chemical treatments, and surge pumping. The following is an approximate log of development procedures.

1. bailing, 2 days (12-hour days)
2. surge block, 3 days with 3000 lbs (1362 kg) sodium hexametaphosphate
3. bailing, 1 day
4. surge block, 2 days with 3500 lbs (1589 kg) Cotey Dry Acid
5. inactive, 2 days
6. bailing, 2 days
7. surge pumping (pump set at 400 feet (122 m)), 3 days

8. surge block, 1 day with 1000 lbs (454 kg) Cotey Dry Acid
9. inactive, 1 day
10. bailing, 1 day
11. surge block, 1 day with 1000 lbs (454 kg) sodium hexametaphosphate
12. bailing, 1 day
13. set test pump to 780 feet (237.9 m)

6.2 PUMPING TESTS

Pumping tests were conducted at KCT #1 during the period May 24 to May 30, 1983. Two types of tests were run: step drawdown and constant discharge.

The test pump, supplied by Stephenson Drilling Company, Fillmore, Utah, consisted of a 14-stage, 10-inch (25.4 cm) vertical lineshaft turbine pump with an 8-inch (20.3 cm) column and was set at 780 feet (237.9 m). Discharge was measured with an in-line flow meter and transported approximately 800 feet (244 m) to the east using 10-inch (25.4 cm) irrigation pipe. Depths to water were measured with electric probes and recorded to the nearest one-hundredth of a foot (3.05×10^{-3} m) when possible. The depth to water in the pumping well was measured in a 1-inch (2.54 cm) sounding tube installed between the pump column and well casing. Water levels were also measured in observation wells ranging from 50 feet (15.3 m) to about 3.6 miles (5.8 km) from KCT #1. Figure 2 and Plate II show the relative locations of these wells. Water level measurements and discharge data are given in Appendix C.

6.2.1 Step Drawdown Pumping Test

The step drawdown test was performed on May 24, 1983. Static water level at the beginning of the test was 42.97 feet (13.1 m) below the measuring point. The test consisted of three 3-hour steps, a fourth 1-hour step, and a fifth 7-minute step. The fourth step was intentionally short because the character of the data was similar to the first three steps. The fifth step was terminated because the water level had dropped to the level of the pump intake.

Average discharge rates ranged from 299 to 456 gpm (19 to 29 lps). The average pumping rate, duration, drawdown, and specific capacity for the end of steps one through four are listed in Table 4. Data from the fifth step are not comparable to the preceeding steps because of the extremely short duration of pumping.

Table 4. Step Drawdown Summary.

Step Number	Average Discharge Rate, gpm (lps)	Engine Speed, rpm	Duration, minutes	Drawdown, feet (m)	Specific Capacity, gpm/ft of drawdown (lps/m of drawdown)
1	299 (19)	800	180	108.9 (33.2)	2.7 (.57)
2	320 (20)	1000	180	226.1 (69.0)	1.4 (.29)
3	340 (21)	1300	180	411.9 (125.6)	0.8 (.17)
4	358 (23)	1400	60	582.4 (177.6)	0.6 (.13)
5	456 (29)	1500	7	675.2 (205.9)	--

Drawdown data during the step test are shown graphically in Figure 3. This diagram shows that the water level stabilized at a lower level after about 30 minutes of pumping at each step. Small increases in the average discharge rate resulted in large increases in drawdown after the first step. This behavior is a reliable indicator of an inefficient well.

Drawdown was observed in observation wells KCE #2 and KCE #6. These wells are located 50 and 500 feet (15.3 and 152.5 m), respectively, from KCT #1. The rates of drawdown were essentially uniform throughout the test and were not affected by the increases in discharge rate or the decreases in water level in the pumping well (Figure 3). Drawdown continued for about 30 minutes in both of these wells after pumping was terminated. Rapid recovery in KCE #2 commenced when depth to water in KCT #1 had recovered most of the way to the pre-pumping level. The drawdown and recovery data and the occurrence of cascading water in KCT #1 indicate that the test well is inefficient and that the upper 100 feet (30.5 m) or so of the aquifer contributes most of the water to the well. Based on the analysis of the step drawdown test data, KCT #1 was rated as capable of producing, on the short-term, about 300 gpm (19 lps) with about 110 feet (33.6 m) of drawdown.

6.2.2 Constant Discharge Pumping Test

The constant discharge test began on May 25, 1983 at noon and continued for 120 hours. Initial water level was 43.00 feet (13.12 m) below the surface. Recovery measurements were made for about 68 hours at the completion of the test. The array of observation wells included KCE #1 through #6 and MX well KB-(0)-1(59) as shown on Figure 2. Water level recorders were set up on the

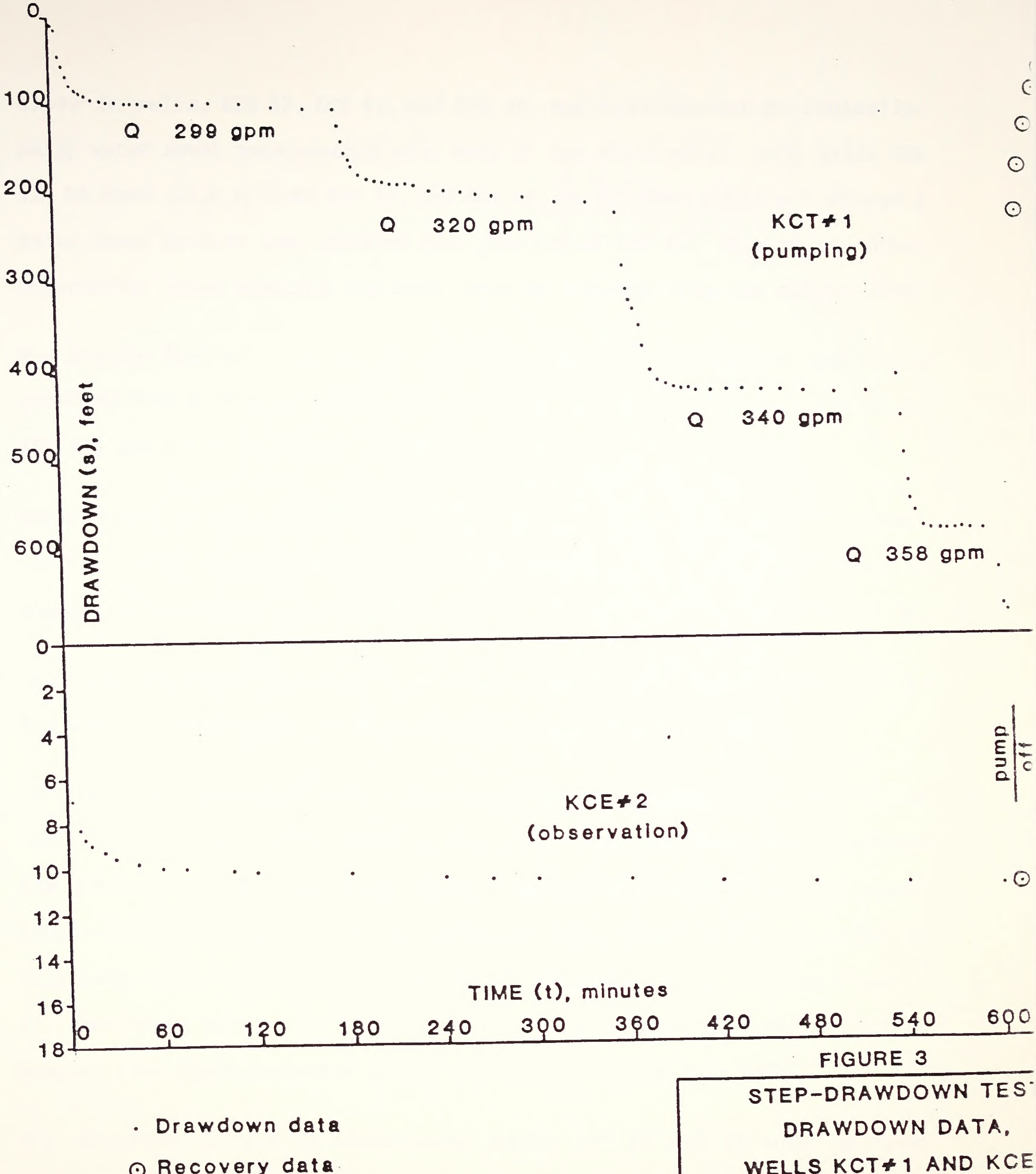

FIGURE 3

STEP-DRAWDOWN TES
DRAWDOWN DATA,
WELLS KCT#1 AND KCE

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close-in wells, KCE #2, KCE #5, and KCE #6, and were checked periodically. Daily water level measurements were made at the other wells. Only wells KCE #2, 50 feet (15.3 m) from KCT #1, and KCE #6, at 500 feet (152.5 m), showed a water level decline that resulted from pumping of KCT #1. None of the other observation wells measured indicated signs of drawdown from the pumping test.

The average discharge rate at the end of the test was 292 gpm (18 lps) which produced a drawdown of 567.1 feet (173.0 m) in KCT #1, 12.9 feet (3.9 m) in KCE #2, and 1.2 feet (0.4 m) in KCT #6.

Water level measurements showed fluctuations within a range of 0.15 feet (0.05 m) in the other observation wells. These fluctuations correspond to changes in barometric pressure and were not in response to pumping of KCT #1.

Drawdown data for the pumping and observations wells are presented in Appendix C. These data are shown graphically in Figures 4 and 5.

Discharge was controlled with a gate valve during the first 2.5 hours of the test. After that, the throttle of the engine was used for control because the gate valve was completely open. Small variations in engine speed resulted in small variations in discharge rate, which in turn resulted in relatively large variations in drawdown in the pumping well (Figures 4 and C-1). The large variations in drawdown in response to small variations in pumping rate again indicated the poor efficiency of the test well.

The drawdown curves in observation wells KCE #2 and #6 were uniform throughout the test (Figures 5, C-3, and C-6). The rates of drawdown were

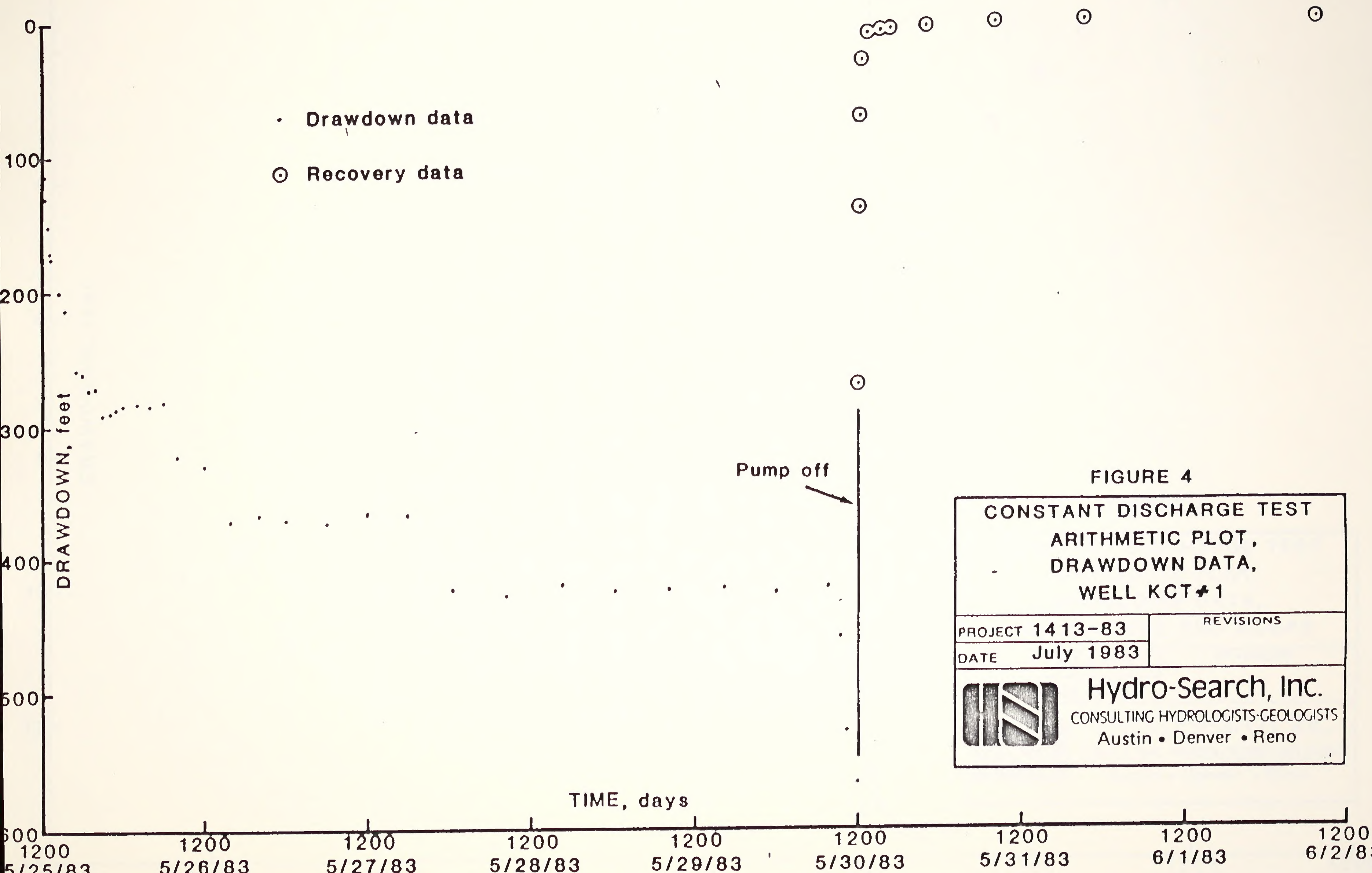

FIGURE 4

CONSTANT DISCHARGE TEST
ARITHMETIC PLOT,
DRAWDOWN DATA,
WELL KCT#1

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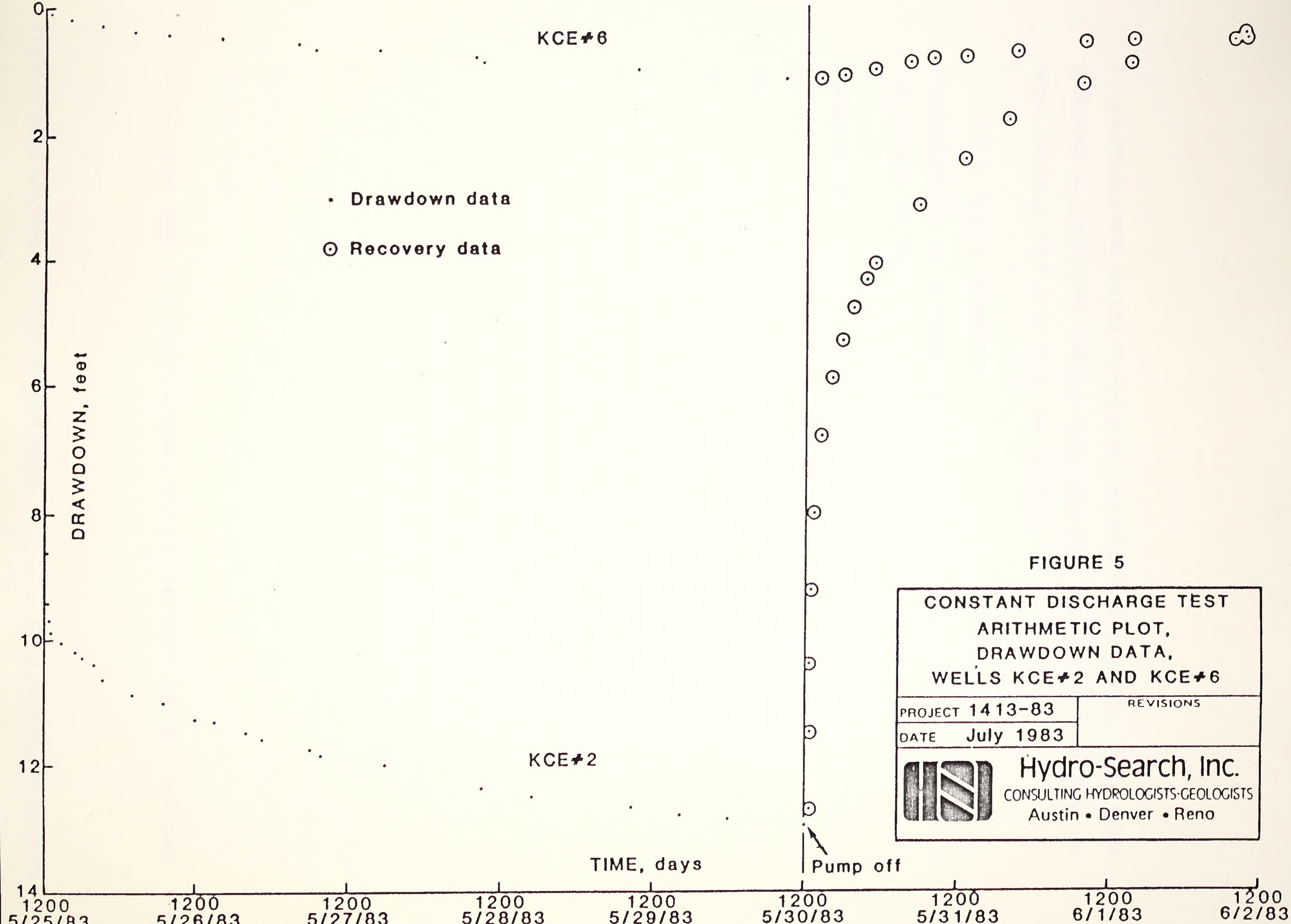

FIGURE 5

CONSTANT DISCHARGE TEST
ARITHMETIC PLOT,
DRAWDOWN DATA,
WELLS KCE#2 AND KCE#6

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to the experience during recovery of the step drawdown test. This again indicates an inefficient pumping well, with most of the production from the upper 100 feet (30.5 m) or so of the aquifer.

6.2.3 Aquifer Parameters

Transmissivity and storage coefficient values were calculated using the Cooper-Jacob straight line and the distance-drawdown methods (Appendix C).

Transmissivity values of the aquifer at KCT #1 are 700 gpd/ft (9 m^2/d) using the drawdown data (Figure C-1, Appendix C) and 12,000 gpd/ft (149 m^2/d) using the recovery data (Figure C-2, Appendix C). The storage coefficient of the aquifer cannot be determined from the pumping well.

Based on the drawdown data, KCE #2 yields a transmissivity value for the aquifer of 28,600 gpd/ft (355 m^2/d) and a storage coefficient of 2.4×10^{-4} (Figure C-3). Using recovery data, KCE #2 yields a transmissivity of 16,100 gpd/ft (200 m^2/d) and a storage coefficient of 1.2×10^{-2} (Figures C-4 and C-5).

Calculations based on drawdown data at KCE #6 yield a transmissivity value for the aquifer of 85,700 gpd/ft (1063 m^2/d) and a storage coefficient of 3.2×10^{-2} (Figure C-6). On the basis of recovery data, KCE #6 yields transmissivity values for the aquifer of 73,400 gpd/ft (910 m^2/d) (Figure C-7) and 59,300 gpd/ft (735 m^2/d) and a storage coefficient of 2.7×10^{-2} (Figure C-8).

Calculations based on distance-drawdown data at the end of the test, indicate

a transmisssivity of 13,400 gpd/ft (166 m^2/d) and a storage coefficient of 4.8×10^{-2} (Figure 6) for the area of Kobeh Valley "C" wellfield.

In summary, transmissivity values calculated from the pumping well and the two observation wells vary by as much as 85,000 gpd/ft (1054 m^2/d) and storage coefficient values vary over two orders of magnitude.

6.3 INTERPRETATION OF AQUIFER TEST RESULTS

The most important information to be obtained from the pumping test program were transmissivity and storage coefficient values and the presence of aquifer boundaries. The aquifer parameters were to be used in a computer model to predict: 1) if a 5000 gpm (316 lps) long-term mill water supply from a wellfield constructed at the Kobeh "C" site is feasible; and 2) what would be the effects of developing such a water supply on neighboring groundwater users. The conditions under which the pumping test was run were far from ideal. The following is a discussion of: 1) well efficiency; 2) conditions necessary for an ideal aquifer test; 3) how the pumping test at KCT #1 differs from the ideal conditions; and 4) evaluation of the pumping test results in light of the divergence from the ideal conditions.

6.3.1 Well Efficiency

The results of the pumping tests indicate that the test well, KCT #1, is hydraulically inefficient. An estimate of the degree of efficiency of a pumping well can be obtained by extending the distance-drawdown line of observation wells KCE #2 and 6 to the radius of KCT #1 (Figure 6). This

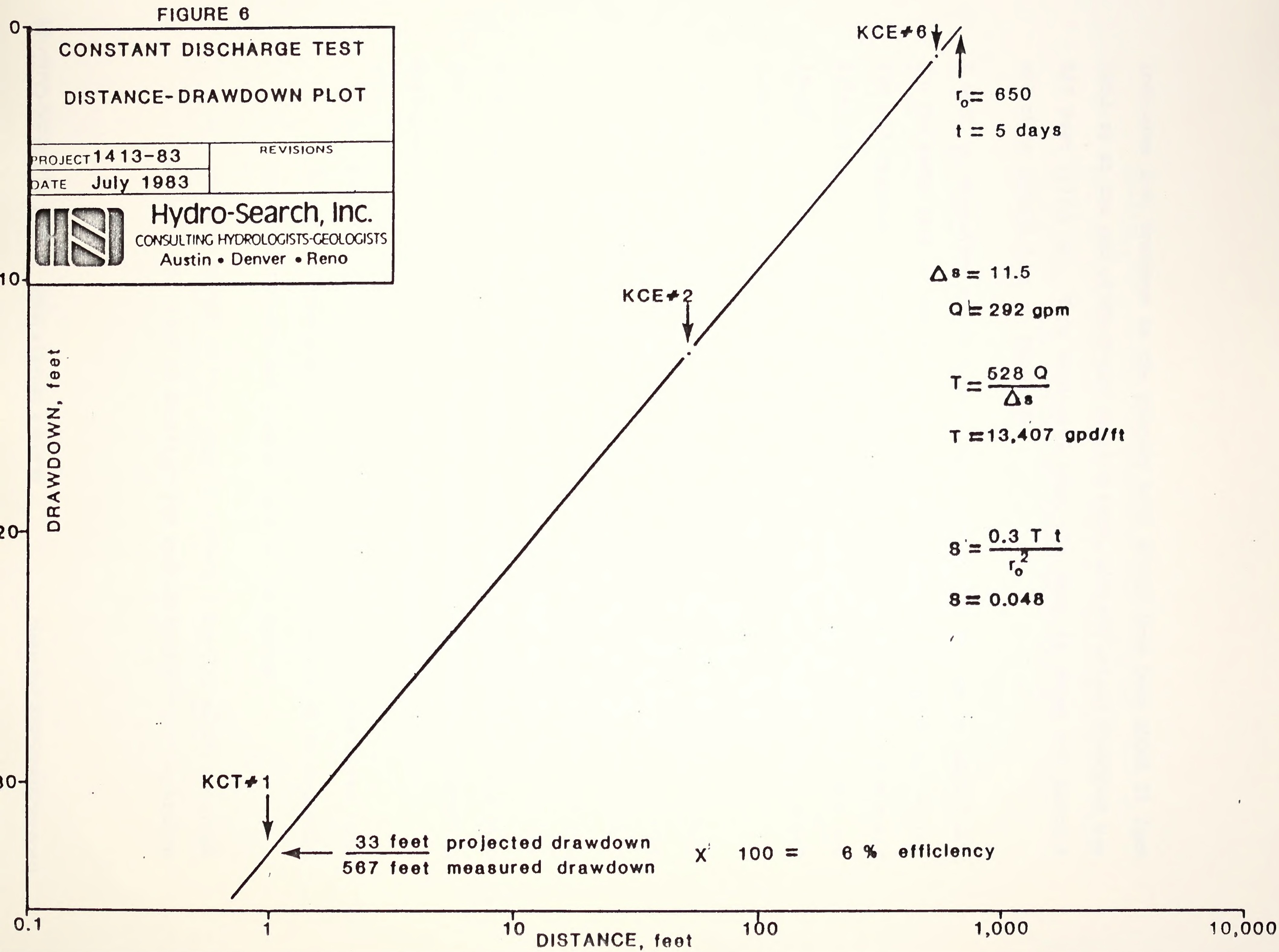
FIGURE 6
CONSTANT DISCHARGE TEST
DISTANCE-DRAWDOWN PLOT
PROJECT 1413-83
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KCE#6
KCE#2
KCT#1
r₀ = 650
t = 5 days
Δs = 11.5
Q = 292 gpm
T = 528 Q / Δs
T = 13,407 gpd/ft
S = 0.3 T t / r₀²
S = 0.048
33 feet projected drawdown / 567 feet measured drawdown X 100 = 6 % efficiency
DRAWDOWN, feet
DISTANCE, feet
0
10
20
30
0.1
1
10
100
1,000
10,000

indicates that drawdown in the pumping well should have been about 33 feet (10.1 m) at the end of the 5-day pumping test, whereas actual drawdown was 567 feet (172.9 m). This indicates that the well is about six percent efficient (calculation on Figure 6).

A well in stratified alluvial materials, such as KCT #1, can be inefficient (in the sense that it does not produce as much water as it apparently should) for two reasons. These are: 1) not all of the water-producing zones are inherently prolific or 2) artificial restrictions, such as mud cake and invasion, caving of sands and gravels, or blocked perforations, exist which impede inflow to part or all of the well bore.

The evidence regarding the cause for the low efficiency of KCT #1 is entirely circumstantial, but this evidence indicates that: 1) the geologic materials throughout the well contain abundant ground water and are potentially prolific producers (Section 6.5) and 2) mud cake on the hole wall and mud invasion of the sands and gravels are restricting inflow of water in the middle and lower portions of the well bore. Existence of a thick mud cake and mud invaded zone in the aquifer is a result of events which occurred during construction of the well. The two most important factors are:

1. The unusually large volume of drilling mud and additives used during well construction. This allowed development of an unusually thick mud cake and mud invaded zone in the aquifer.

2. The long period of time (approximately 5 months) which occurred between the start of construction and the beginning of agressive

development procedures designed to remove the mud. This period allowed the drilling mud to "set up", plug casing and screen perforations and interstices between sand and gravel grains, and become extremely difficult to remove.

Development work on the upper part of the producing zone performed shortly after construction (December 30-January 16) resulted in partial development of this section. This is the zone which produced most of the water during the pumping tests. Despite the aggressive well development program undertaken in mid-April, only marginal improvements in well efficiency were obtained.

Other theoretical conditions must also be met; however, the five listed below are most germane to evaluation of the pumping test of KCT #1. The other theoretical conditions will not be discussed further in this report.

In general, these theoretical, ideal conditions do not exist in nature. The effects of diversion from the ideal in most cases are so small that use of these analytical techniques are considered valid. In the case of KCT #1, some of these assumptions were violated to a major degree and resulted in variable and highly questionable values for transmissivity and storage coefficient. The following section discusses the causes for violation of these assumptions and the effects on the results.

6.3.2 Ideal Aquifer Testing Conditions

Utilization of the methods and equations discussed in Appendix C for

calculation of the transmissivity and storage coefficient values from pumping test data assumes the following ideal conditions:

1. the aquifer is homogeneous and isotropic
2. the aquifer is of infinite areal extent
3. the test well penetrates the full saturated thickness of the aquifer
4. the observation wells penetrate the full saturated thickness of the aquifer
5. the pumping well and observation wells allow free passage of water from the aquifer into the well bore

6.3.3 Conditions in the Vicinity of KCT #1 which Affected Aquifer Performance Analysis

The aquifer at Kobeh "C" consists of interstratified layers of gravel, sand, silt, and clay. It is not homogeneous and isotropic when examined closely. The aquifer approximates the ideal conditions when the total thickness of the alluvial deposits is considered as a whole. If the pumping well were hydraulically efficient, water would enter from the entire saturated thickness; however, the middle and lower sections were blocked off by mud cake and a thick mud-invaded zone in the aquifer (as discussed above). Therefore, only the upper 100 feet (30.5 m) or so were contributing water to the well. When the pumping water level was drawn down below this level, the upper portion of the aquifer drained by gravity (cascading water) down the well bore. The pumping test was then no longer an aquifer test but a test of the efficiency of the test well.

The second condition, the aquifer is of infinite extent, was met since no discernible boundaries were encountered during the test while pumping approximately 300 gpm (19 lps). This does not preclude the possibility that boundaries could be encountered if the well could have been pumped at a higher rate for a longer period of time. It does mean, however, that results of the pumping test were not affected appreciably by boundaries.

The third and fourth conditions were not met except for Observation Well KCE #2. The test well and all other observation wells were completed well above the base of the aquifer. Water could not be pumped from below a depth of 845 feet because the well was completed at that depth and the horizontal stratification of the materials impeded upward flow from below the well. Therefore, the effects on the whole aquifer could not be evaluated. Likewise is the case with the observation wells (except KCE #2). They would not show response of the total aquifer because the aquifer is multilayered and the observation wells were not completed in the lower portions of the aquifer. The effects of this would not be as great in this test because the bottom of the well was not tested and both observation wells that responded to pumping were completed deep enough to monitor the response of the upper 100 feet or so of aquifer.

The fifth condition, that water flow freely from the aquifer into the test well and observation wells, was not met in the test well and probably not in KCE #2. This condition had the most profound effect of any of the deviations from ideal conditions on the results of the pumping test as discussed above. Well KCE #6 was drilled with organic polymer and was bailed and flushed to

remove the drilling fluid. The efficiency of this well was probably much greater relative to KCT #1 and KCE #2. However, drawdown measurements in this well may not have been representative of the aquifer response by gravity drainage of the upper section because the well was in hydraulic communication with lower, non-produced (in the sense of this aquifer test) portions of the aquifer. In this case, the measured drawdown levels may have been affected by positive pressure from the lower zones and may be higher than the actual drawdown would have been if the well had been completed in only the upper zones affected by the pumping

6.3.4 Effects of Non-Ideal Conditions on Results of the Aquifer Test

The inefficiency of the test well had a major adverse impact on the results of the aquifer test. Only about the upper 100 feet (30.5 m) of the aquifer were in good hydraulic connection with the well bore. The test results do not reflect conditions in the entire aquifer because only the upper zone was stressed by pumping. This severely limits the use of the data collected during the test in evaluation of the aquifer at Kobeh "C". The aquifer parameters calculated on the basis of these data are of doubtful validity because of the non-ideal drawdown-recovery response to gravity draining of the developed upper portion of the aquifer. The wide range of transmissivity and storage coefficient values (Section 6.2.3) is the result.

Hydro-Search, Inc. considers that projections or estimates of aquifer hydraulic parameters based on the knowledge of conditions in the test well and the calculated values for transmissivity and storage coefficient are of

doubtful validity and should not be used for definitive projections of long-term performance of a Kobeh "C" wellfield.

6.4 WATER QUALITY

Water samples were collected at approximately 24-hour intervals during the constant discharge test and analyzed for temperature, pH, and electrical conductivity. Temperature varied between 13 and 14°C, pH between 7.5 and 7.6, and electrical conductivity remained constant at about 700 micromhos/cm at 25°C. These data are given in Table 5 and indicate that the quality of water did not change significantly during the test.

Table 5. Water Quality Measurements.

Sample No.	Date	Time	Temperature °C	pH	Electrical Conductivity (micromhos/cm @ 25°C)
1	5/26/83	1200	13.0	7.5	700
2	5/27/83	1200	13.5	7.5	700
3	5/28/83	1200	13.5	7.6	700
4	5/29/83	1100	13.5	7.6	700
5	5/30/83	1100	14.0	7.6	700

The sample collected at the end of the test was submitted for laboratory analysis of principal ions and trace metals. Results of the laboratory analyses are given in Table 6.

Laboratory analyses show that the water is a calcium-rich mixed cation sulfate type and, according to USGS criteria, falls into the "very hard"

Table 6. Water Quality Data.

Well	KCT #1	Q = 292 gpm
Date	05/30/83	t = 7140 minutes
Temperature (°C)	14	
pH	7.6	
Total Dissolved Solids (evaporated)	502	
Electrical Conductivity	730	
Constituent		
HCO_3	126	
CO_3	0	
Cl	34	
SO_4	200	
F	0.4	
NO_3 (as NO_3)	4.3	
PO_4 (as P)	1.25	
Na	37	
K	6.5	
Ca	68	
Mg	24	
SiO_2	36	
Al	<0.02	
As	0.007	
Ba	<0.4	
B	0.1	
Cd	<0.01	
Cr	<0.02	
Pb	<0.05	
Hg	<0.0005	
Se	<0.005	
Ag	0.01	
Cu	<0.02	
Fe	0.09	
Mn	0.11	
Zn	0.02	
Hardness as $CaCO_3$	270	

Note: All analyses are in mg/l except pH which is in units and electrical conductivity which is in micromhos/cm @ 25°C.

classification.

Except for manganese, the water is below U.S.EPA Primary and Secondary and Nevada Division of Health drinking water standards. (Table 7). Manganese exceeds the U.S.EPA secondary standard and is at the maximum recommended level of the Nevada Division of Health standard. The total dissolved solids concentration is at the maximum recommended level in the U.S.EPA Secondary Standards but is well below the Nevada Division of Health Standard.

Table 7. Drinking Water Standards.

U.S. EPA Primary Standards	mg/l	U.S. EPA Secondary Standards	mg/l	Nevada Division of Health Standards	mg/l
Arsenic	0.05*	Chloride	250	Chloride	400
Barium	1.*	Copper	1		
Cadmium	0.010*	Iron	0.3	Iron	0.60
Chromium	0.05*	Manganese	0.05	Manganese	0.10
Lead	0.05*	pH**	6.5-8.5		
Mercury	0.002*	Sulfate	250	Sulfate	500
Nitrate (as NO_3)	45.*	TDS	500	TDS	1000
Selenium	0.01*	Zinc	5*		
Silver	0.05*			Magnesium	150
Fluoride	1.4-2.4*,***				

* Also included in Nevada Division of Health primary standards.

** pH units.

*** Depends on average annual maximum daily air temperatures.

There was some concern during well construction that the ground water in the vicinity of Kobeh C may contain hydrogen sulfide because of the "rotten egg odor" in water bailed or air lifted from a few of the exploration wells and KCT #1. This odor was not present after development and pumping of KCT #1, and is probably related to the breakdown of drilling fluid additives such as organic polymer and lignite.

6.5 EVALUATION OF PUMPING TEST PROGRAM

The major objectives of the Phase II hydrology program were to determine the feasibility of installing a 5000 gpm (316 lps) wellfield at the Kobeh "C" site and to predict the effects of developing the project water supply on neighboring ground-water users. The pumping test program did not provide direct evidence (in the sense of producing high discharge rates at acceptable drawdown) that Exxon's water requirement is available at Kobeh "C". Transmissivity and storage coefficient values for the aquifer calculated on the basis of the pumping test data were not adequate for use in the appropriate computer models to predict long-term drawdowns away from the wellfield.

However, the work during Phase II provided substantial indirect evidence that a 5000 gpm (316 lps) water supply can be developed at the site. Hydro-Search, Inc. is of the strong opinion, that the project water supply can be developed at Kobeh "C" by a series of properly constructed wells based on the following evidence:

1. Drill cuttings from all holes drilled at Kobeh "C" indicate that coarse sand and gravel occur throughout the alluvial section penetrated. Some of the gravel occurs as rounded grains more than 3/4-inch (1.9 cm) in diameter.

2. Geophysical logs from Kobeh Valley indicate that the alluvial materials are sorted so that the sand and gravel fractions occur as layers which can yield large quantities of water to a properly constructed well.

3. Geological and geophysical logs (1 and 2, above) are similar to those of prolific ground-water producing stratified alluvial valley fill deposits in other Nevada hydrographic basins (Section 5.3, Phase I report).

4. The upper 100 feet (30.5 m) of the aquifer produced most of the water during the pumping test (approximately 300 gpm) with only a small amount of drawdown (1.2 feet (.37 m)) in the observation well (KCE #6) located 500 feet (152.5 m) away. No drawdown was observed in observation well KCE #5 located 3575 feet (1090.4 m) from the pumping well.

5. The geophysical log of well KCT #1 (Plate VII) shows that the upper section of aquifer which produced most of the water during the pumping tests is similar to the lower portion of the log. Those portions of the log corresponding to screened sections in the well should be the most prolific producing zones, and these potentially

high-producing zones occur in the lower portion of the well below the zone which produced water during the pumping test.

6. The log for KCE #2 indicates over 1000 feet (305 m) of saturated alluvial materials exist in this area of Kobeh Valley.

7. Loss of drilling fluids to the formation occurred during the drilling indirectly indicating a high degree of permeability in the aquifer.

PUMPING TEST DATA

METHODS

Transmissivity (T) and storage coefficient (S) can be calculated using both drawdown and recovery data. S can be estimated only from data collected from observation wells. T was determined using the Cooper-Jacob modified non-equilibrium method using the formula (UOP-Johnson, 1975):

$$T = \frac{264\ Q}{\Delta s}$$

where:

T = transmissivity, gpd/foot,
Q = well discharge, gpm, and
Δs = drawdown (feet) per logarithmic cycle of time.

Δs is obtained from a semilogarithmic plot of drawdown vs. time.

The storage coefficient (S) was determined from the drawdown and calculated recovery graphs using the formula (UOP-Johnson, 1975):

$$S = \frac{0.3\ Tt_o}{r^2}$$

where:

S = storage coefficient, dimensionless,
T = transmissivity, gpd/foot,
t_o= intercept of the drawdown straight line plot at zero drawdown, days, and
r = distance from pumped well to observation well where drawdown measurements were taken, feet.

Aquifer parameters and well efficiency were also determined using the Distance-Drawdown method (Figure 6). T was estimated using the formula (UOP-Johnson, 1975):

$$T = \frac{528\ Q}{\Delta s}$$

where:

T = transmissivity, gpd/foot,
Q = well discharge, gpm, and
Δs = drawdown (feet) per logarithmic cycle of distance

Δs is obtained from a semilogarithmic plot of drawdown vs. distance.

S was determined using the formula (UOP-Johnson, 1975):

$$S = \frac{0.3\, Tt}{r_o^2}$$

where:

S = storage coefficient, dimensionless,
T = transmissivity, gpd/foot,
t = time since pumping started, in days,
r_o = intercept at zero drawdown (feet) of extended straight line.

Well efficiency was estimated by dividing the projected drawdown at the radius of the drill hole by the measured drawdown and multiplying by 100 (Figure 6).

CONSTANT DISCHARGE TEST

PUMPING WELL KCT #1

DRAWDOWN DATA

Precision Meter Flow Meter
Olympic Probe
Radius of Pumping Well 8" (12" Hole)
Measuring Point: Stilling Well = 1.0 AGL

Depth of Pump 780
Pump On: 5/25/83 1200
Pump Off: 5/30/83 1200
Duration of Test: 120 hours
Static Water Level: 43.00

Time	t	Reading	s	Discharge	Comments
05/25/83					
1200	0	43.00	0		
1201	1	55.67	12.67		
1203	3	75.31	32.31	596	
1205	5	96.28	53.28	473	
1207	7	110.91	67.91	423	
1210	10	126.29	83.29	372	
1215	15	143.41	100.41	327/313	
1220	20	155.96	112.96	303	
1226	26	161.93	118.93	327	
1230	30	166.40	123.40	318	
1235	35	169.34	126.34	307	
1240	40	175.12	132.12	334	
1245	45	183.44	140.44	334	
1250	50	187.58	144.58	317	
1300	60	194.21	151.21	314	T = 12°C
1310	70	200.67	157.67	314	
1320	80	209.37	166.37	322	
1330	90	214.67	171.67	314	
1340	100	221.02	178.02	317	
1400	120	225.54	182.54	307	
1420	140	237.28	194.28	318	
1440	160	247.34	204.34	310	
1500	180	251.31	208.31	309	
1530	210	257.34	214.34	310	
1601	241	317.18	274.18	338	
1630	270	313.92	270.92	318	
1700	300	299.94	256.94	307	
1800	360	302.95	259.95	310	T = 12.5°C
1900	420	313.98	270.98	312	
2000	480	313.03	270.03	308	

CONSTANT DISCHARGE TEST (Cont'd)

PUMPING WELL KCT #1

DRAWDOWN DATA

Time	t	Reading	s	Discharge	Comments
2101	541	333.46	290.46	313	T = 12.5°C
2200	601	331.92	288.92	294	
2300	661	329.45	286.45	315	
2400	721	326.45	283.45	305	
05/26/83					
0205	846	325.32	287.32	308	
0400	966	325.72	282.72	278	
0600	1086	323.70	280.70	290	T = 12.5°C
0800	1200	365.13	322.13	327	
1200	1440	372.54	329.54	299	T = 13°C
1600	1680	415.41	372.41	300	
2000	1920	410.83	367.83	297	T = 13°C
05/27/83					
0000	2160	414.13	371.13	296	
0600	2520	416.94	373.94	294	
1200	3880	410.00	367.00	291	
1800	3240	409.83	366.83	287	
05/28/83					
0026	3626	464.90	421.90	289	
0832	4112	471.42	428.42	289	
1620	4600	462.54	419.54	265	
05/29/83					
0001	5061	467.43	424.43	285	
0802	5542	466.00	423.00	283	
1630	6030	464.49	421.49	299	
05/30/83					
0003	6483	468.27	425.27	279	
0739	6939	463.93	420.93		
0824	6984	465.00	422.0		
0919	7039	466.06	423.06		

CONSTANT DISCHARGE TEST (Cont'd)

PUMPING WELL KCT #1

DRAWDOWN DATA

Time	t	Reading	s	Discharge	Comments
0930	7050	551.8	508.8		
0941	7061	572.1	529.1		
0953	7073	573.8	530.8		
1021	7101	572.18	529.18		
1125	7165	569.91	526.91		
1143	7183	602.6	559.6		
1150	7190	610.43	567.43		
1155	7195	610.14	567.14		
1200	7200				Test terminated

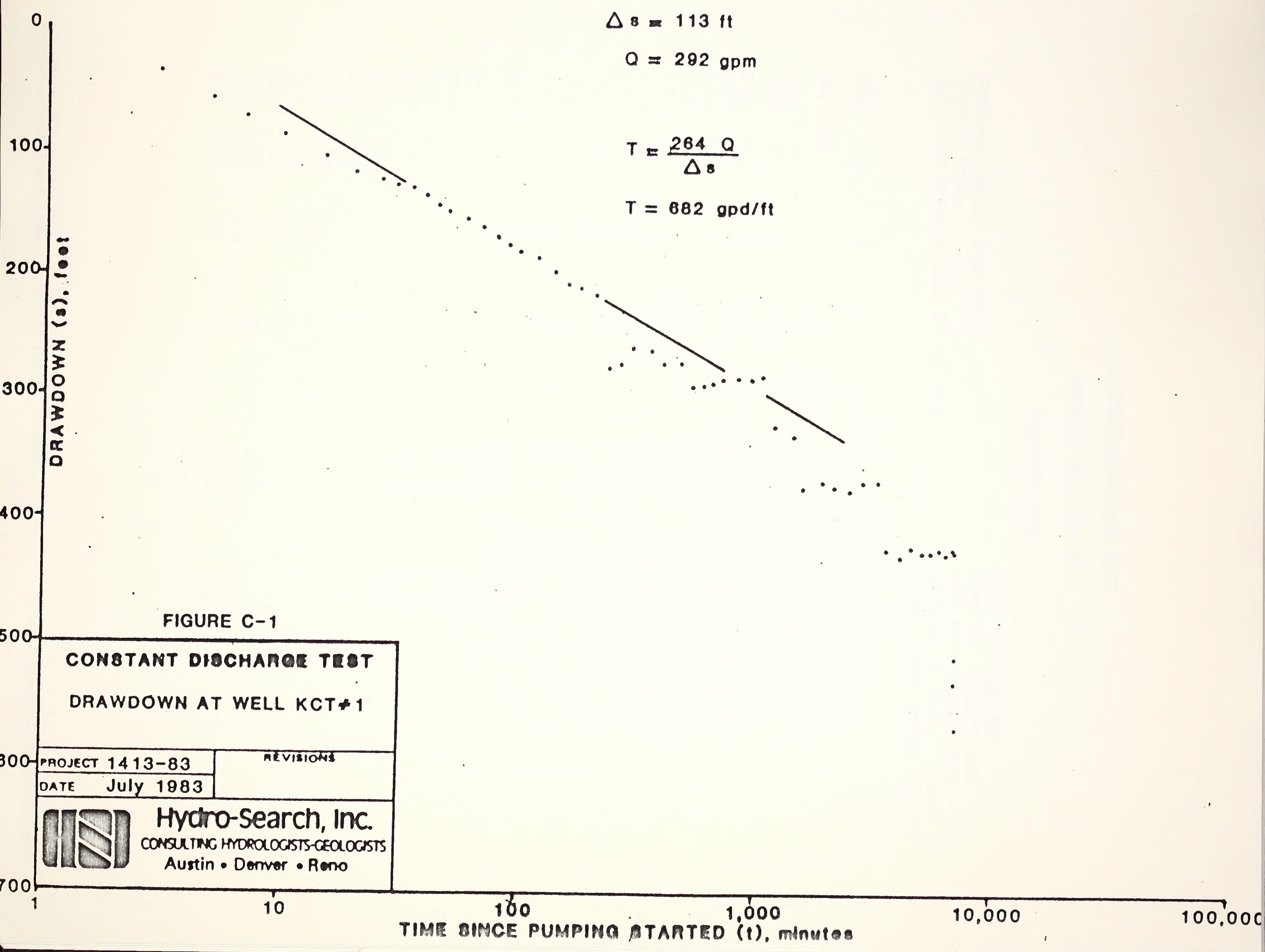

FIGURE C-1

CONSTANT DISCHARGE TEST

DRAWDOWN AT WELL KCT#1

PROJECT 1413-83

DATE July 1983

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CONSTANT DISCHARGE TEST

PUMPING WELL KCT #1

RECOVERY DATA

Depth of Pump 780'
Pump On: 5/25/83 1200
Pump Off: 5/30/83 1200
Duration of Test: 5 days
Static Water Level: 43.00

Precision Meter Flow Meter
Olympic Probe
Radius of Pumping Well 8" (12" hole)

Time	t	t'	t/t'	Reading	s'
05/30/83					
1200	7200	0	---		
1201	7201	1	7201	453.68	410.68
1203	7203	3	2401	404.39	361.39
1204	7204	4	1801	382.1	339.1
1205	7205	5	1441	365.2	322.2
1206	7206	6	1201	348.2	305.2
1207	7207	7	1030	330.1	287.1
1208	7208	8	901	312.8	269.8
1209	7209	9	801	296.1	253.1
1210	7210	10	721	279.0	236.0
1213	7213	13	555	225.6	182.6
1216	7216	16	451	204.0	161.0
1219	7219	19	380	181.7	138.7
1226	7226	26	278	137.0	94.0
1230	7230	30	241	115.4	72.4
1235	7235	35	207	91.2	48.2
1240	7240	40	181	70.55	27.55
1245	7245	45	161	60.45	17.45
1250	7250	50	145	57.61	14.61
1300	7260	60	121	55.13	12.13
1311	7271	71	102	54.02	11.02
1322	7282	82	89	53.38	10.38
1330	7290	90	81	53.27	10.27
1340	7300	100	73	52.94	9.94
1400	7320	120	61	52.40	9.40
1420	7340	140	52	51.95	8.95
1440	7360	160	46	51.61	8.61
1500	7382	182	41	51.15	8.15
1530	7410	210	35	50.93	7.93
1600	7441	241	31	50.41	7.41

CONSTANT DISCHARGE TEST (Cont'd)

PUMPING WELL KCT #1

RECOVERY DATA

Time	t	t'	t/t'	Reading	s'
1630	7470	270	28	50.04	7.04
1700	7500	300	25	49.91	6.91
1802	7562	362	21	49.34	6.31
1907	7627	427	18	48.96	5.96
05/30/83					
2005	7685	485	16	48.69	5.69
2105	7745	545	14	48.40	5.40
2201	7801	601	13	48.16	5.16
2301	7861	661	12	47.87	4.87
05/31/83					
0603	8283	1083	7.6	46.66	3.66
0820	8420	1220	6.9	46.34	3.34
1306	8706	1506	5.8	45.78	2.78
1621	8901	1701	5.2	45.47	2.47
2128	9208	2008	4.6	45.00	2.00
06/01/83					
0749	9829	2629	3.7	44.36	1.36
1555	10315	3115	3.3	44.08	1.08
06/02/83					
0741	11261	4061	2.8	43.69	0.69

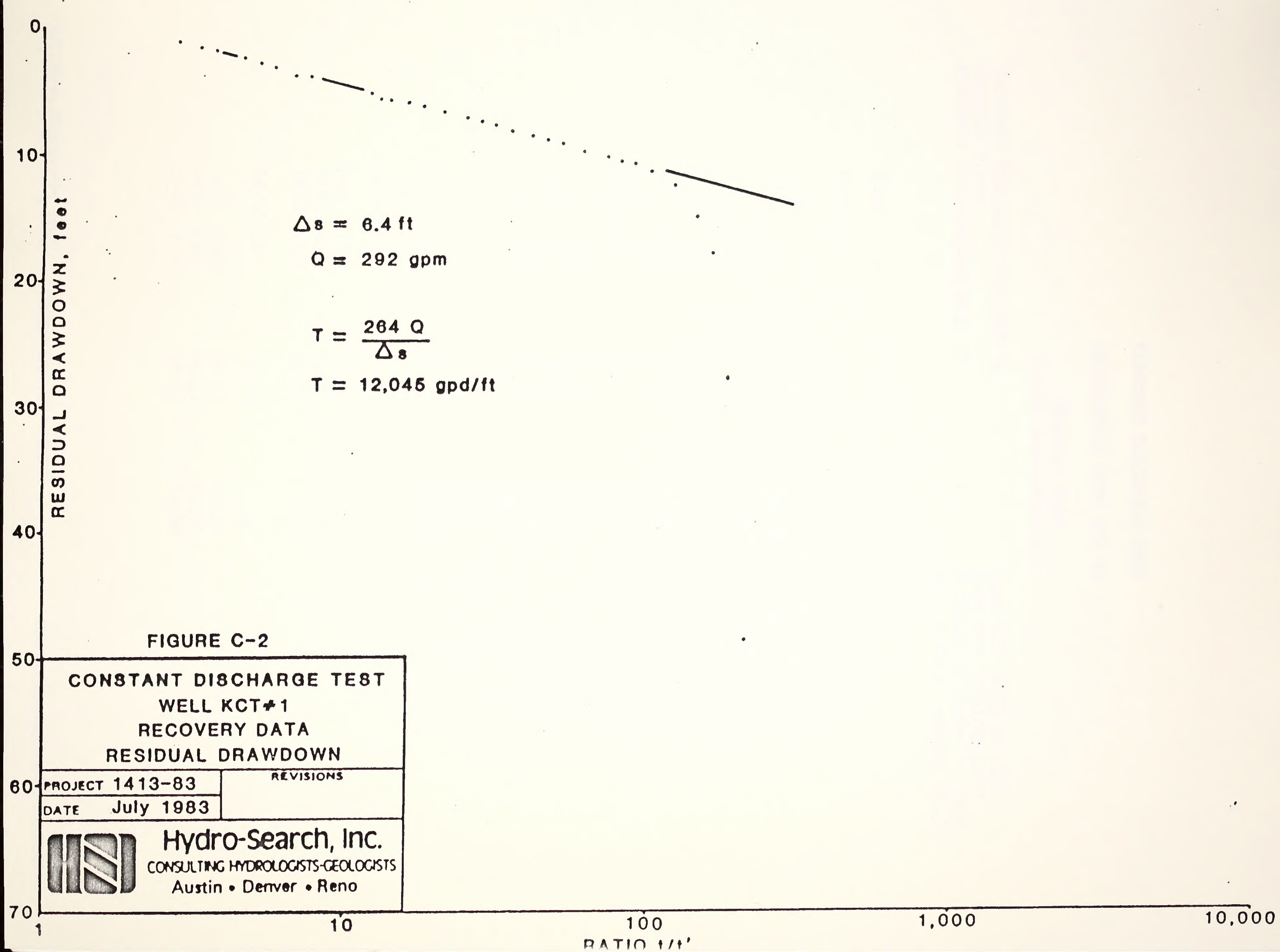

FIGURE C-2

CONSTANT DISCHARGE TEST
WELL KCT#1
RECOVERY DATA
RESIDUAL DRAWDOWN

PROJECT 1413-83	REVISIONS
DATE July 1983	

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CONSTANT DISCHARGE TEST

OBSERVATION WELL KCE #2

DRAWDOWN DATA
(Probe Measurements)

Constant Discharge Test-KCT #1
Olympic Probe
Distance from Pumping Well 50'

Pump On: 5/25/83 1200
Pump Off: 5/30/83 1200
Duration of Test: 5 days
Static Water Level: 41.20

Time	t	Reading	s
05/25/83			
1200	0	41.20	0
1451	171	51.26	10.06
2131	571	51.84	10.64
05/26/83			
0706	1146	52.24	11.04
1452	1612	52.54	11.34
05/27/83			
0006	2166	52.80	11.60
0603	2523	52.97	11.77
0753	2633	53.05	11.85
1802	3242	53.21	12.01
05/28/83			
0904	4144	53.58	12.38
1648	4628	53.68	12.48
05/29/83			
0831	5571	53.85	12.65
0945	5625	53.91	12.71
1624	6024	53.97	12.77
05/30/83			
0004	6484	54.04	12.84
0835	6995	54.13	12.93
1145	7185	54.13	12.93

CONSTANT DISCHARGE TEST

OBSERVATION WELL KCE #2

DRAWDOWN DATA
(Recorder Chart Readings)

Constant Discharge Test-KCT #1
Olympic Probe
Distance from Pumping Well 50'

Pump On: 5/25/83 1200
Pump Off: 5/30/83 1200
Duration of Test: 5 days
Static Water Level: 41.20

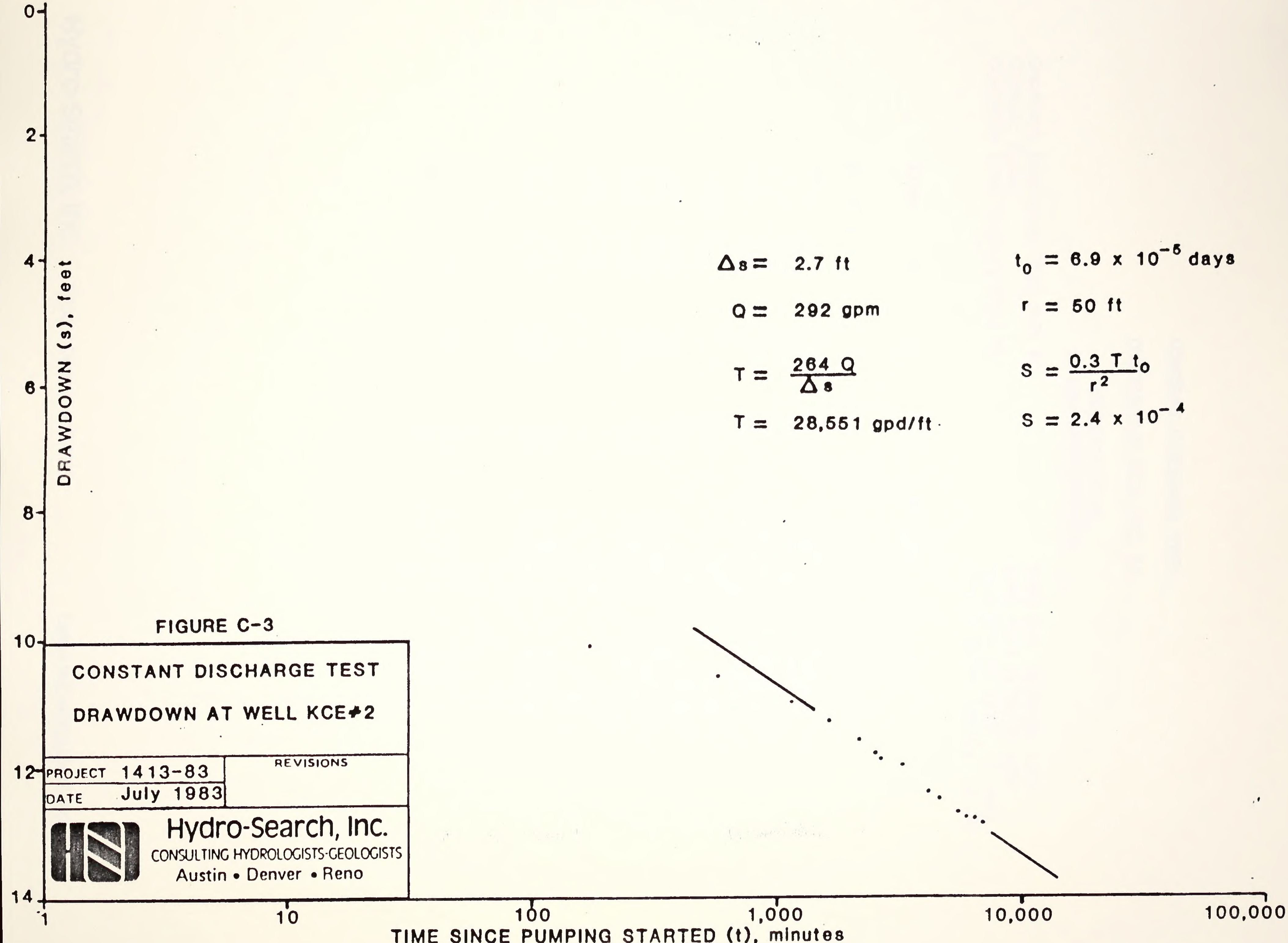
Time	t	Reading	s
05/25/83			
1200	0	41.2	0
1215	15	49.8	8.6
1230	30	50.6	9.4
1245	45	50.9	9.7
1300	60	51.1	9.9
1315	75	51.2	10.0
1330	90	51.3	10.1
1345	105	51.4	10.2
1400	120	51.4	10.2
1415	135	51.5	10.3
1430	150	51.5	10.3
1445	165	51.6	10.4
1500	180	51.2	10.0
1515	195	51.2	10.0
1530	210	51.3	10.1
1545	225	51.3	10.1
1600	240	51.3	10.1
1700	300	51.4	10.2
1800	360	51.5	10.3
1900	420	51.5	10.3
2000	480	51.6	10.4
2100	540	51.6	10.4
2200	600	51.8	10.6
2400	720	51.8	10.6
05/26/83			
0200	840	52.1	10.9
0400	960	52.2	11.0
0600	1080	52.2	11.0
0800	1200	52.3	11.1
1200	1440	52.5	11.3

CONSTANT DISCHARGE TEST (Cont'd)

OBSERVATION WELL KCE #2

DRAWDOWN DATA
(Recorder Chart Readings)

Time	t	Reading	s
1600	1680	52.6	11.4
2000	1920	52.7	11.5
05/27/83			
0000	2160	52.8	11.6
0600	2520	53.0	11.8
1400	3000	53.2	12.0
05/28/83			
0100	3660	53.3	12.1
0530	3990	53.4	12.2
0915	4155	53.6	12.4
1700	4620	53.7	12.5
05/29/83			
0315	5235	53.8	12.6
1000	5640	53.9	12.7
2100	6300	54.0	12.8
05/30/83			
0300	6660	54.1	12.9
1200	7200	54.1	12.9



DRAWDOWN (s), feet
0
2
4
6
8
10
12
14
1
10
100
1,000
10,000
100,000
TIME SINCE PUMPING STARTED (t), minutes
Δs = 2.7 ft
Q = 292 gpm
T = 264 Q / Δs
T = 28,551 gpd/ft
t0 = 6.9 x 10^-5 days
r = 50 ft
S = 0.3 T t0 / r^2
S = 2.4 x 10^-4
FIGURE C-3
CONSTANT DISCHARGE TEST
DRAWDOWN AT WELL KCE#2
PROJECT 1413-83
DATE July 1983
REVISIONS
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CONSTANT DISCHARGE TEST

OBSERVATION WELL KCE #2

RECOVERY DATA
(Probe Measurements)

Constant Discharge Test-KCT #1
Olympic Probe
Distance from Pumping Well 50'

Pump On: 5/25/83 1200
Pump Off: 5/30/83 1200
Duration of Test: 5 days
Static Water Level: 41.20

Time	t	t'	t/t'	Reading	s'
05/30/83					
1500	7380	180	41	47.87	7.67
1945	7665	465	16	46.00	4.80
2145	7785	585	13	45.56	4.36
2300	7860	660	12	45.32	4.12
05/31/83					
0606	8286	1086	7.6	44.35	3.15
1315	8715	1515	5.6	43.62	2.42
2130	9210	2010	4.6	42.99	1.79
06/01/83					
0754	9834	2634	3.7	42.46	1.26
1545	10305	3105	3.3	42.13	0.93
06/02/83					
0748	11268	4068	2.8	41.77	0.57
9957			2.7	41.73	0.53

CONSTANT DISCHARGE TEST

OBSERVATION WELL KCT #2

RECOVERY DATA
(Recorder Chart Readings)

Constant Discharge Test KCT #1
Weather Measure Recorder
Distance from Pumping Well 50'
Top of Casing

Pump On: 5/25/83 1200
Pump Off: 5/30/83 1200
Duration of Test: 5 days
Static Water Level: 41.2

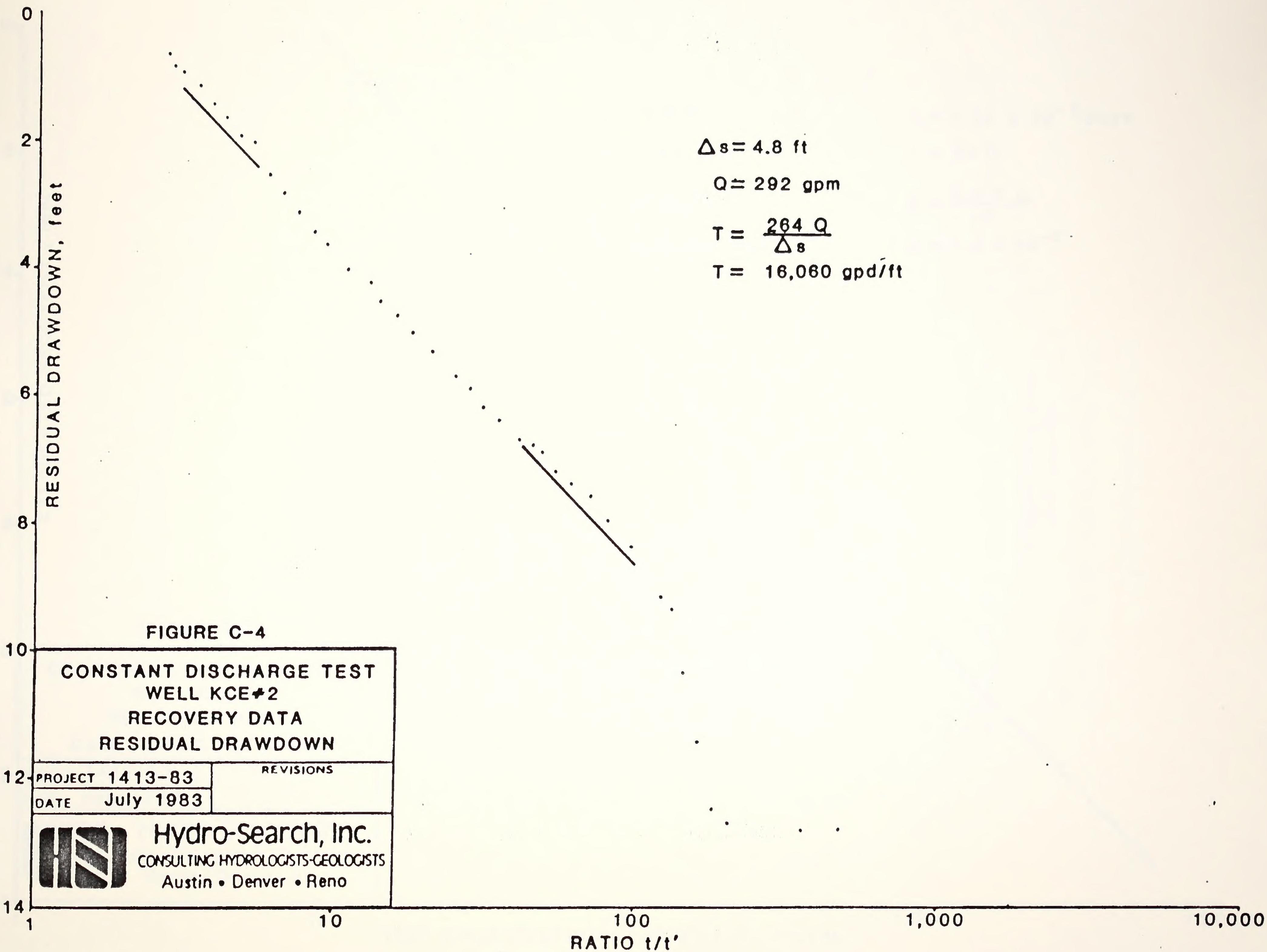
Time	t	t'	t/t'	Reading	s'
05/30/83					
1200	7200	0	---	54.1	12.9
1215	7215	15	481	54.1	12.9
1220	7220	20	361	54.1	12.9
1235	7235	35	207	54.0	12.8
1240	7240	40	181	53.8	12.6
1245	7245	45	161	52.7	11.5
1250	7250	50	145	51.6	10.4
1255	7255	55	132	50.6	9.4
1300	7260	60	121	50.4	9.2
1315	7275	75	97	49.6	8.4
1330	7290	90	81	49.2	8.4
1345	7305	105	70	48.8	7.6
1400	7320	120	61	48.6	7.4
1415	7335	135	54	48.4	7.2
1430	7350	150	49	48.1	6.9
1445	7365	165	45	48.0	6.8
1500	7380	180	41	47.9	6.7
1530	7470	270	28	47.6	6.4
1600	7440	240	31	47.4	6.2
1630	7470	270	28	47.1	5.9
1700	7500	300	25	46.9	5.7
1800	7560	360	21	46.5	5.3
1900	7620	420	18	46.2	5.0
2000	7680	480	16	45.9	4.7
2100	7740	540	14	45.7	4.5
2200	7800	600	13	45.4	4.2
2400	7920	720	11	45.2	4.0
05/31/83					
0230	8070	870	9.3	44.8	3.6
0400	8160	960	8.5	44.6	3.4

CONSTANT DISCHARGE TEST (Cont'd)

OBSERVATION WELL KCT #2

RECOVERY DATA
(Recorder Chart Readings)

Time	t	t'	t/t'	Reading	s'
0630	8310	1110	7.5	44.3	3.1
0900	8460	1260	6.7	44.0	2.8
1200	8640	1440	6.0	43.7	2.5
05/31/83					
1545	8865	1665	5.3	43.2	2.0
2000	9120	1920	4.8	43.1	1.9
2400	9360	2160	4.3	42.8	1.6
06/01/83					
0500	9660	2460	3.9	42.6	1.4
1200	10080	2880	3.5	42.3	1.1
2030	10590	3390	3.1	42.1	0.9
06/02/83					
0300	10980	3780	2.9	42.0	0.8
0800	11280	4080	2.8	41.8	0.6



0
2
4
6
8
10
12
14
RESIDUAL DRAWDOWN, feet
1
10
100
1,000
10,000
RATIO t/t'
Δs = 4.8 ft
Q = 292 gpm
T = 264 Q / Δs
T = 16,060 gpd/ft
FIGURE C-4
CONSTANT DISCHARGE TEST
WELL KCE#2
RECOVERY DATA
RESIDUAL DRAWDOWN
PROJECT 1413-83
DATE July 1983
REVISIONS
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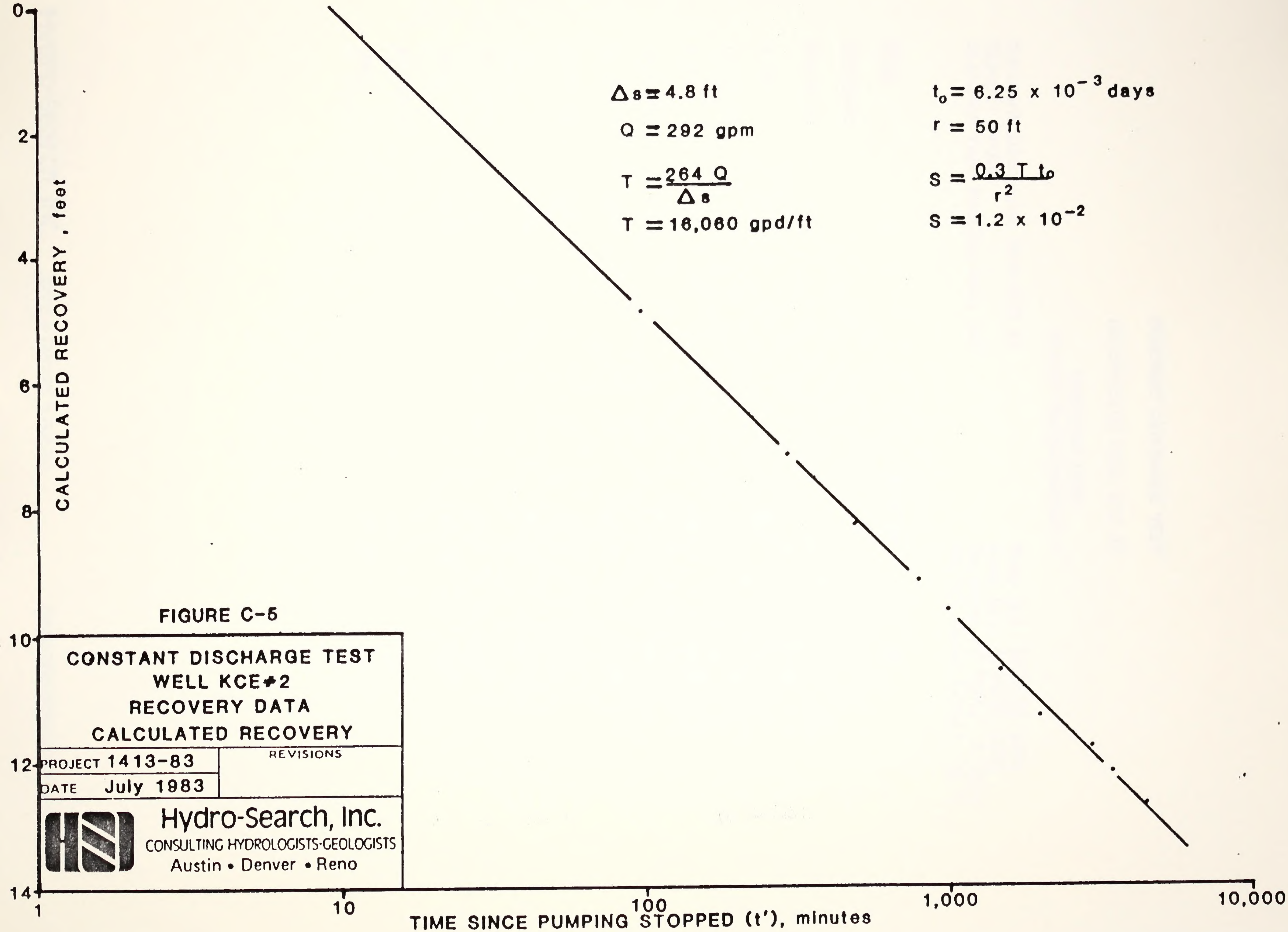

Δs = 4.8 ft
Q = 292 gpm
T = 264 Q / Δs
T = 16,060 gpd/ft
t₀ = 6.25 x 10^-3 days
r = 50 ft
S = 0.3 T t₀ / r²
S = 1.2 x 10^-2
CALCULATED RECOVERY , feet
0
2
4
6
8
10
12
14
1
10
100
1,000
10,000
TIME SINCE PUMPING STOPPED (t'), minutes
CONSTANT DISCHARGE TEST
WELL KCE#2
RECOVERY DATA
CALCULATED RECOVERY
PROJECT 1413-83
DATE July 1983
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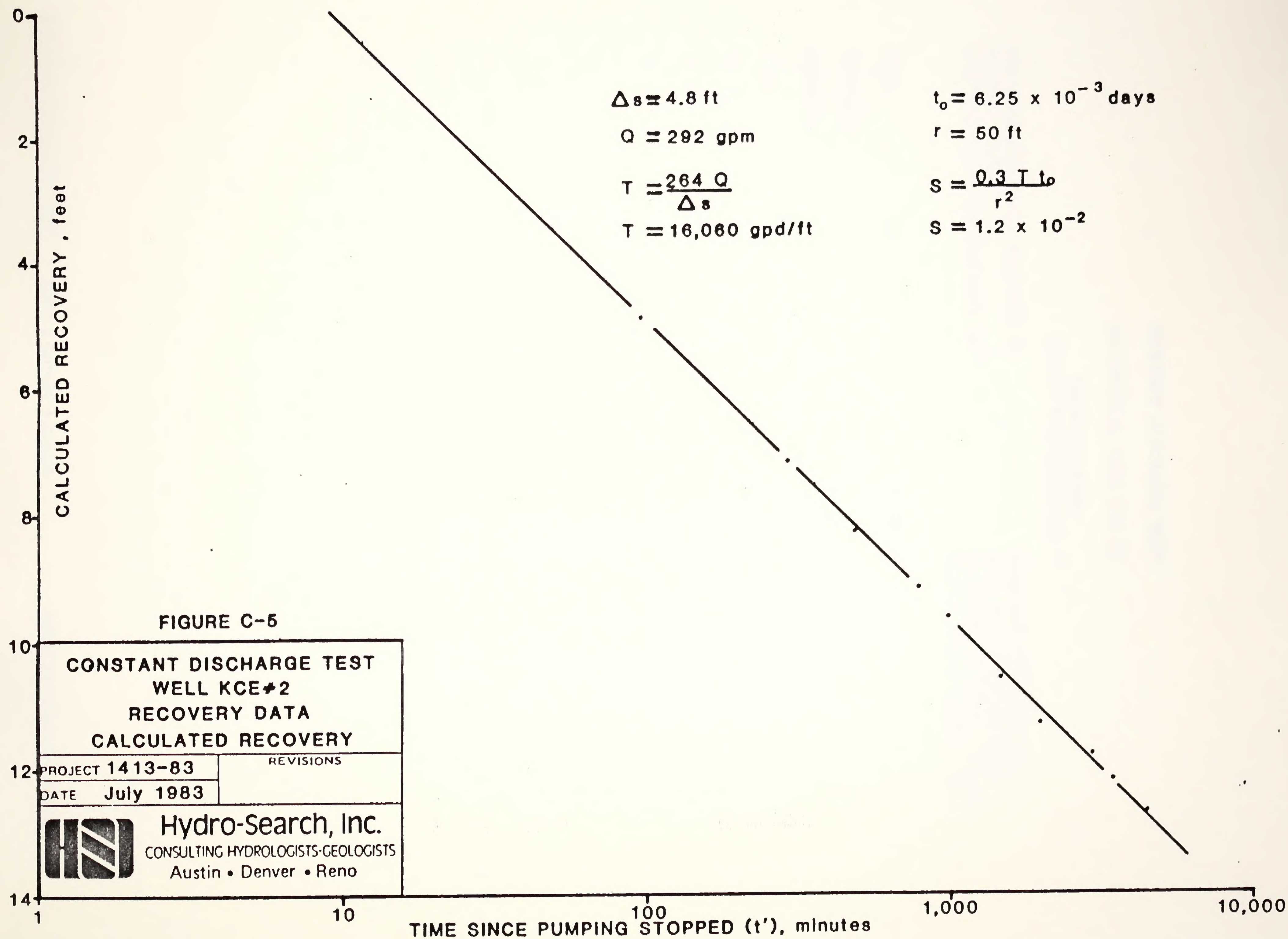
FIGURE C-5


Δs = 4.8 ft
Q = 292 gpm
T = 264 Q / Δs
T = 16,060 gpd/ft
t₀ = 6.25 x 10⁻³ days
r = 50 ft
S = 0.3 T t₀ / r²
S = 1.2 x 10⁻²
CALCULATED RECOVERY, feet
0
2
4
6
8
10
12
14
1
10
100
1,000
10,000
TIME SINCE PUMPING STOPPED (t'), minutes
FIGURE C-5
CONSTANT DISCHARGE TEST
WELL KCE#2
RECOVERY DATA
CALCULATED RECOVERY
PROJECT 1413-83
DATE July 1983
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CONSTANT DISCHARGE TEST

OBSERVATION WELL KCE #6

DRAWDOWN DATA
(Probe Measurements)

Constant Discharge Test-KCT #1
Olympic Probe
Distance from Pumping Well 500'

Pump On: 5/25/83 1200
Pump Off: 5/30/83 1200
Duration of Test: 5 days
Static Water Level: 41.7

Time	t	Reading	s
Drawdown			
05/25/83			
1200	0	41.7	0
05/26/83			
0731	1171	42.14	0.44
05/27/83			
0637	2557	42.37	0.67
05/28/83			
0914	4154	42.57	0.87
05/29/83			
0922	5602	42.72	1.02
05/30/83			
0845	7005	42.87	1.17

CONSTANT DISCHARGE TEST

OBSERVATION WELL KCE #6

DRAWDOWN DATA
(Recorder Chart Readings)

Constant Discharge Test KCT #1
Weather Measure Recorder/Olympic Probe
Distance from Pumping Well 500'

Pump On: 5/25/83 1200
Pump Off: 5/30/83 1200
Duration of Test: 5 days
Static Water Level: 41.7

Time	t	Reading	s
05/25/83			
1200	0	41.7	0
1300	60	41.8	0.1
1600	240	41.9	0.2
2100	540	42.0	0.3
05/26/83			
0200	840	42.1	0.4
1400	1680	42.2	0.5
05/27/83			
0400	2400	42.3	0.6
1700	3180	42.4	0.7
05/28/83			
0800	4080	42.5	0.8
05/29/83			
0900	5580	42.7	1.0
05/30/83			
1200	7200	42.9	1.2

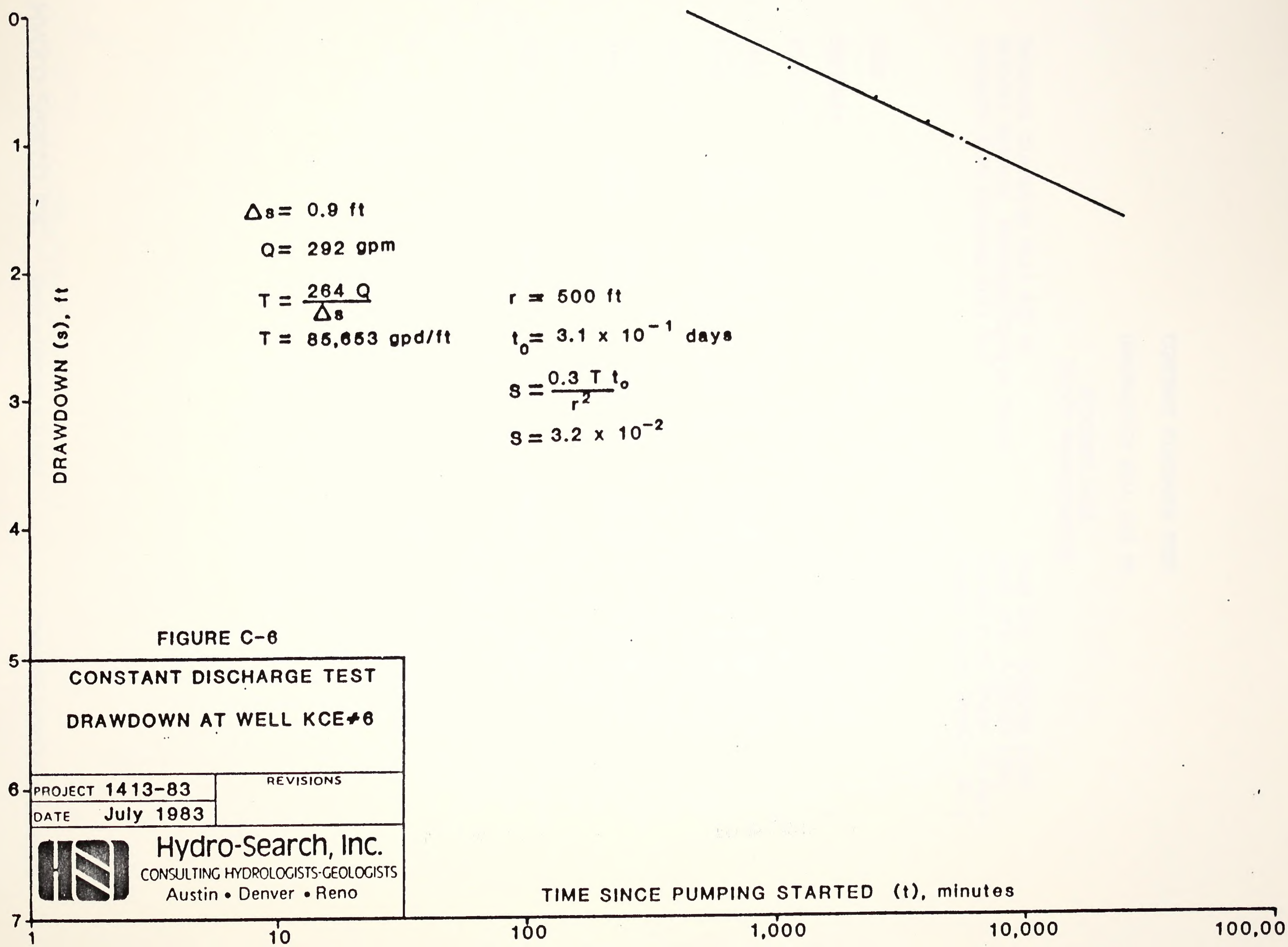

FIGURE C-6

CONSTANT DISCHARGE TEST

DRAWDOWN AT WELL KCE#6

PROJECT 1413-83	REVISIONS
DATE July 1983	

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CONSTANT DISCHARGE TEST

OBSERVATION WELL KCE #6

RECOVERY DATA
(Probe Measurements)

Constant Discharge Test KCT #1
Weather Measure Recorder/Olympic Probe
Distance from Pumping Well 500'

Pump On: 5/25/83 1200
Pump Off: 5/30/83 1200
Duration of Test: 5 days
Static Water Level: 41.7

Time	t	t'	t/t'	Reading	s'
Recovery					
05/31/83					
0811	8411	1211	6.9	42.52	0.82
1330	8730	1530	5.7	42.50	0.80
2134	9214	2014	4.6	42.42	0.72
06/01/83					
0807	9847	2647	3.7	42.30	0.60
1550	10310	3110	3.3	42.25	0.55
06/02/83					
0938	11378	4178	2.7	42.17	0.47

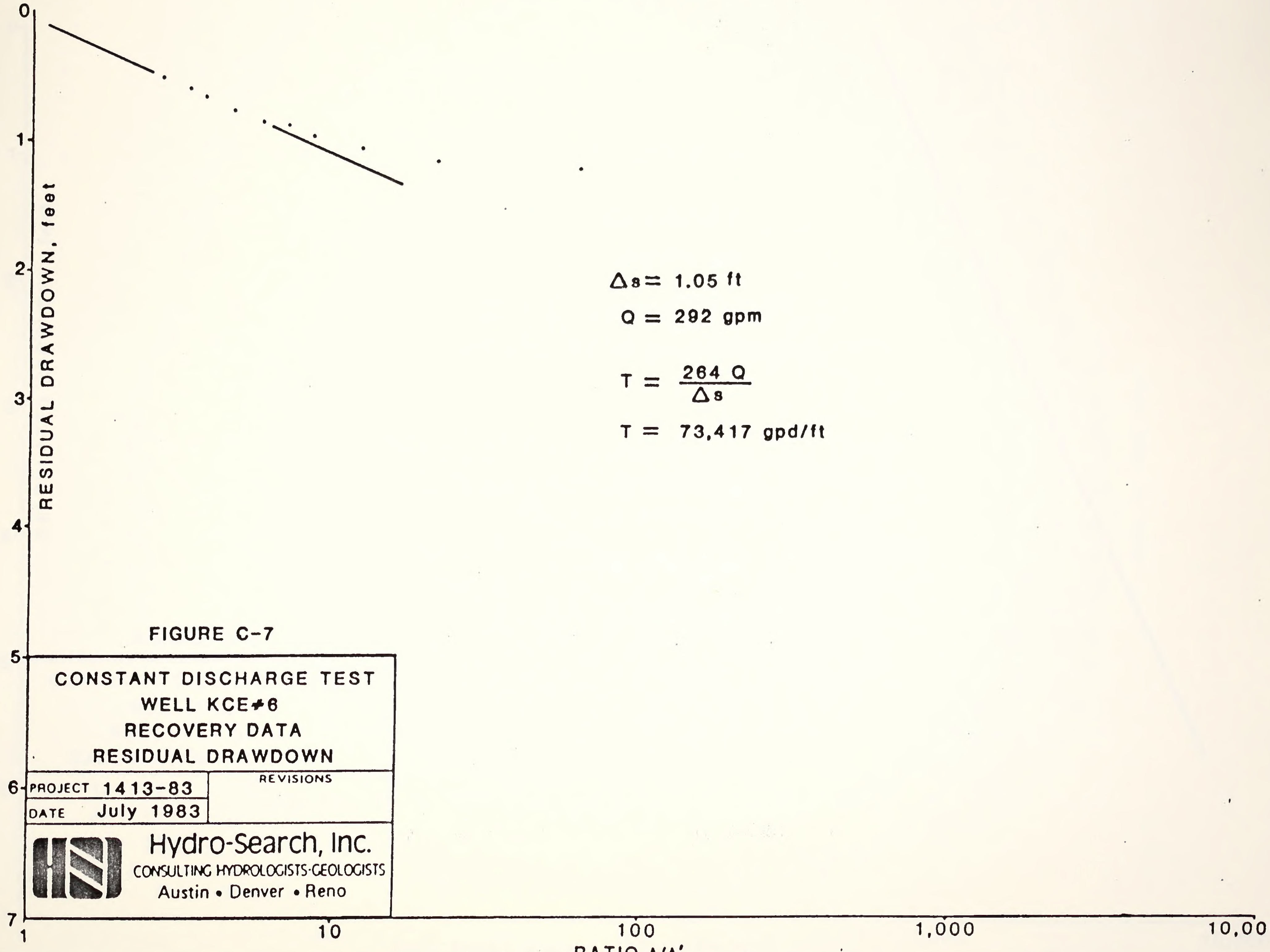

FIGURE C-7

CONSTANT DISCHARGE TEST
WELL KCE#6
RECOVERY DATA
RESIDUAL DRAWDOWN

PROJECT	1413-83	REVISIONS
DATE	July 1983	

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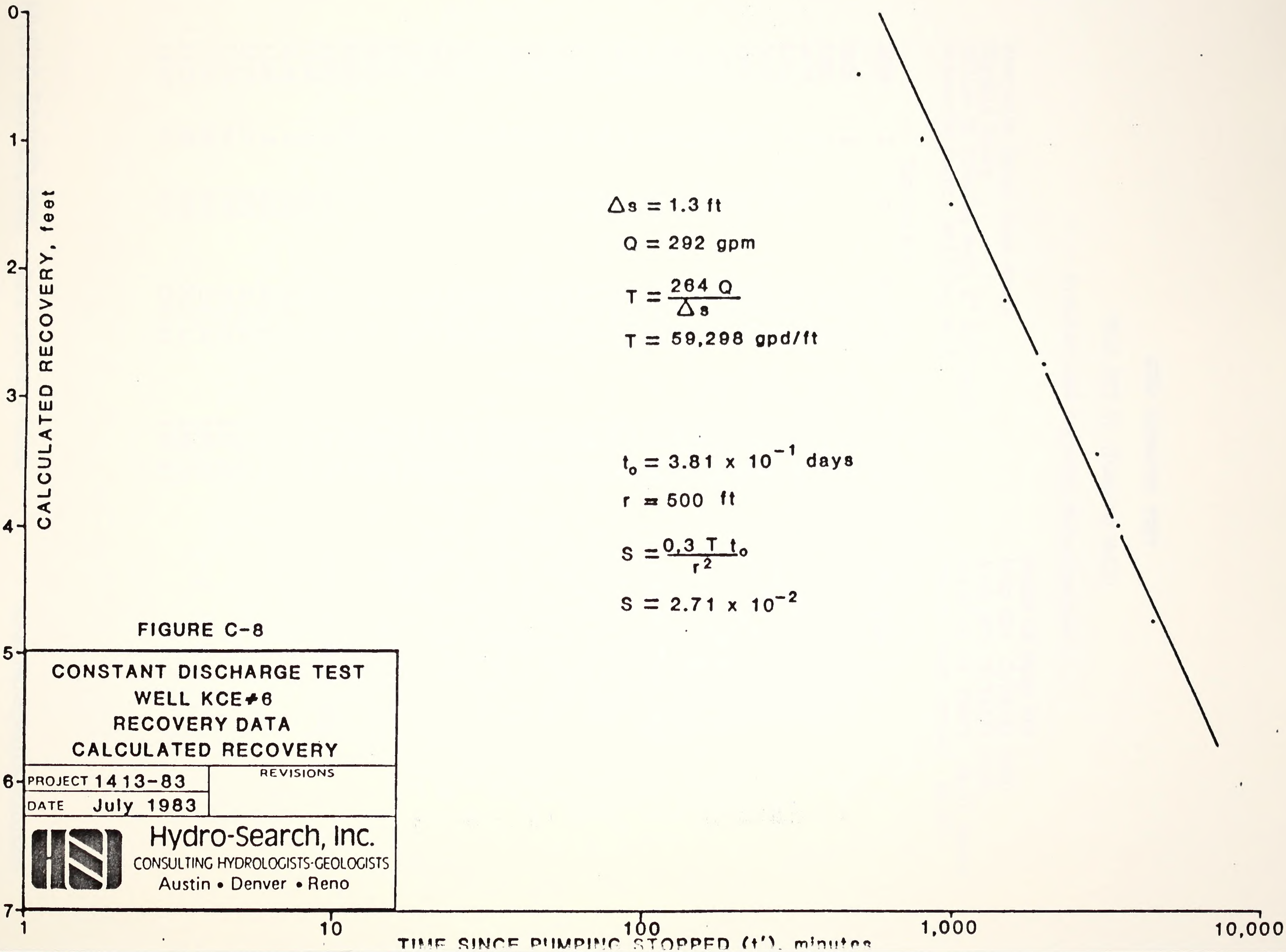

FIGURE C-8

CONSTANT DISCHARGE TEST
WELL KCE#6
RECOVERY DATA
CALCULATED RECOVERY

PROJECT 1413-83
DATE July 1983
REVISIONS

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STEP DRAWDOWN TEST

WELL KCT #1 (Pumping Well)

Drawdown and Recovery Measurements*

Precision Meter Flow Meter
Olympic Probe
Radius of Pumping Well 8" (12" Hole)
Measuring Point: Stilling Well

Depth of Pump 780
Pump On: 5/24/83 0800
Pump Off: 5/24/83 1810
Duration of Test: 10.17 hours
Static Water Level: 42.97

Time	t	Cumulative t	Reading	s or s'	Comments
0800	0		42.97	—	
0801	1		54.38	11.41	
0803	3		70.00	27.03	
0805	5		88.65	45.68	
0807	7		101.34	58.37	
0809	9		110.75	67.78	
0812	12		122.38	79.41	
0815	15		127.18	84.21	
0818	18		130.40	87.43	
0821	21		133.72	90.75	
0825	25		136.79	93.82	
0831	31		139.14	96.17	
0835	35		141.04	98.07	
0840	40		141.25	98.28	
0847	47		142.88	99.91	
0850	50		143.36	100.39	
0900	60		145.25	102.28	
0910	70		143.86	100.89	
0920	80		145.25	102.28	
0930	90		145.10	102.13	
0940	100		142.47	99.50	
1000	120		145.08	102.11	
1021	141		148.77	105.80	
1040	160		150.86	107.89	
1059	179		151.84	108.87	
1102	2	182	171.07	128.10	Step #2 RPM = 950
1104	4	184	187.84	144.87	
1106	6	186	199.67	156.70	
1108	8	188	208.75	165.78	
1110	10	190	215.45	172.48	
1115	15	195	225.02	182.05	
1120	20	200	230.04	187.07	
1125	25	205	233.12	190.15	
1130	30	210	234.44	191.47	

STEP DRAWDOWN TEST

WELL KCT #1 (Pumping Well)

Drawdown and Recovery Measurements* (Cont'd)

Time	t	Cumulative t	Reading	s or s'	Comments
1135	35	215	235.43	192.46	
1140	40	220	236.02	193.05	
1145	45	225	236.29	193.32	
1150	50	230	238.42	195.45	
1200	60	240	243.57	200.60	
1210	70	250	244.51	201.54	
1220	80	260	244.83	201.86	
1230	90	270	248.80	205.83	
1240	100	280	250.57	207.60	
1300	120	300	252.76	209.76	
1320	140	320	257.86	214.89	
1340	160	340	257.71	214.74	
1359	179	359	269.05	226.08	
1403	3	363	330.60	287.63	Step #3 RPM = 1200
1405	5	365	355.3	312.3	
1407	7	367	367.8	324.8	
1409	9	369	377.7	334.7	
1412	12	372	395.7	352.7	
1416	16	376	418.9	375.9	
1420	20	380	446.1	403.1	
1425	25	385	456.7	413.7	
1430	30	390	461.0	418.0	
1435	35	395	463.5	420.5	
1440	40	400	464.6	421.6	
1445	45	405	466.2	423.2	
1450	50	410	468.1	425.1	
1500	60	420	468.0	425.0	
1510	70	430	468.3	425.3	
1520	80	440	468.1	425.1	
1533	93	453	468.9	425.9	
1545	105	465	468.6	425.6	
1600	120	480	470.7	427.7	
1620	140	500	470.9	427.9	
1640	160	520	471.8	428.8	
1700	179	539	454.9	411.9	
1702	2	542	499.1	456.1	Step #4 (short) RPM = 1425
1704	4	544	541.3	498.3	
1706	6	546	572.0	529.0	

STEP DRAWDOWN TEST

WELL KCT #1 (Pumping Well)

Drawdown and Recovery Measurements* (Cont'd)

Time	t	Cumulative t	Reading	s or s'	Comments
1708	8	548	592.4	549.4	
1710	10	550	606.1	563.1	
1715	15	555	620.7	577.7	
1720	20	560	623.7	580.7	
1726	26	566	625.8	582.8	
1730	30	570	625.3	582.3	
1735	35	575	625.0	582.0	
1740	40	580	623.5	580.5	
1745	45	585	623.7	580.7	
1753	53	593	624.8	581.8	
1759	59	599	625.4	582.4	
1802	2	602	669.0	626.0	Step #5 (Short) - RPM = 1500
1805	5	605	710.8	667.8	
1807	7	607	718.2	675.2	
1807.3	7.3				Driller suddenly shut pump off-sucking air. Pump again on for ~ 1 min (by mistake) shut down @ 1810
1817		617	272.0	229.0	
1820		620	222.9	179.9	
1825		625	177.9	134.9	
1830		630	136.4	93.4	
1835		635	101.7	58.7	
1840		640	73.4	30.4	
1843		643	63.0	20.0	Cascading water stops
1900		660	50.8	7.8	Obs. well showed no recovery until about the time cascading water stops.

* Shown graphically on Figure 3.

MISCELLANEOUS WATER LEVEL MEASUREMENTS

TAKEN DURING PUMP TEST

WELL KCE #1

Date	Time	Measuring Device	Reading	Taken By
05/07/83	1905	Olympic Probe	84.00	RAF
05/08/83	1255	Olympic Probe	83.94	RAF
05/09/83	1800	Olympic Probe	84.30	RAF
05/10/83	1710	Olympic Probe	84.34	RAF
05/10/83	1710	Olympic Probe	83.99	RAF
05/11/83	1500	Olympic Probe	84.00	RAF
05/23/83	2015	Olympic Probe	83.99	RAF
05/25/83	1105	Olympic Probe	83.98	RAF
05/26/83	0930	Olympic Probe	83.98	RAF
05/27/83	1450	Olympic Probe	83.95	RAF
05/28/83	1335	Olympic Probe	83.96	RAF
05/29/83	1700	Olympic Probe	83.93	RAF
05/30/83	1720	Olympic Probe	83.91	RAF
05/31/83	1430	Olympic Probe	83.91	RAF
06/01/83	1520	Olympic Probe	83.95	RAF
06/02/83	0845	Olympic Probe	84.00	RAF

WELL KCE #3

Date	Time	Measuring Device	Reading	Taken By
05/07/83	1930	Olympic Probe	79.76	RAF
05/08/83	1710	Olympic Probe	79.65	RAF
05/09/83	1830	Olympic Probe	79.67	RAF
05/10/83	1740	Olympic Probe	79.68	RAF
05/11/83	1445	Olympic Probe	79.75	RAF
05/23/83	2115	Olympic Probe	79.60	RAF
05/25/83	1035	Olympic Probe	79.65	RAF
05/25/83	1035	Olympic Probe	79.67	RAF
05/26/83	1020	Olympic Probe	79.65	RAF
05/27/83	1525	Olympic Probe	79.63	RAF
05/28/83	1410	Olympic Probe	79.64	RAF
05/29/83	1725	Olympic Probe	79.54	RAF
05/30/83	1750	Olympic Probe	79.52	RAF
05/31/83	1410	Olympic Probe	79.54	RAF
06/01/83	1440	Olympic Probe	79.67	RAF
06/02/83	0830	Olympic Probe	79.89	RAF

MISCELLANEOUS WATER LEVEL MEASUREMENTS

TAKEN DURING PUMP TEST

WELL KCE #4

Date	Time	Measuring Device	Reading	Taken By
05/07/83	1940	Olympic Probe	88.40	RAF
05/08/83	1700	Olympic Probe	88.31	RAF
05/09/83	1820	Olympic Probe	88.33	RAF
05/10/83	1730	Olympic Probe	88.40	RAF
05/11/83	1435	Olympic Probe	88.43	RAF
05/23/83	2130	Olympic Probe	88.44	RAF
05/25/83	1025	Olympic Probe	88.39	RAF
05/26/83	1010	Olympic Probe	88.39	RAF
05/27/83	1515	Olympic Probe	88.37	RAF
05/28/83	1400	Olympic Probe	88.37	RAF
05/29/83	1715	Olympic Probe	88.32	RAF
05/30/83	1740	Olympic Probe	88.30	RAF
05/31/83	1400	Olympic Probe	88.33	RAF
06/01/83	1450	Olympic Probe	88.35	RAF
06/02/83	0820	Olympic Probe	88.44	RAF

WELL KCE #5

Date	Time	Measuring Device	Reading	Taken By
05/07/83	1830	Olympic Probe	51.55	RAF
05/09/83	0845	Olympic Probe	51.45	RAF
05/11/83	1515	Olympic Probe	51.57	RAF
05/23/83	2005	Olympic Probe	51.70	RAF
05/25/83	0619	Olympic Probe	51.75	RAF
05/26/83	0620	Olympic Probe	51.75	RAF
05/26/83	0940	Olympic Probe	51.73	RAF
05/27/83	1352	Olympic Probe	51.73	RAF
05/28/83	1324	Olympic Probe	51.74	RAF
05/29/83	1647	Olympic Probe	51.70	RAF
05/30/83	1710	Olympic Probe	51.70	RAF
05/31/83	1420	Olympic Probe	51.68	RAF
06/01/83	1510	Olympic Probe	51.68	RAF
06/02/83	0854	Olympic Probe	51.72	RAF

MISCELLANEOUS WATER LEVEL MEASUREMENTS

TAKEN DURING PUMP TEST

WELL 20/52-17

Date	Time	Measuring Device	Reading	Taken By
05/07/83	2015	Olympic Probe	16.39	RAF
05/08/83	1925	Olympic Probe	16.35	RAF
05/09/83	1600	Olympic Probe	16.34	RAF
05/10/83	1920	Olympic Probe	16.35	RAF
05/11/83	1650	Olympic Probe	16.36	RAF
05/23/83	2040	Olympic Probe	16.40	RAF
05/25/83	1005	Olympic Probe	16.40	RAF
05/26/83	0900	Olympic Probe	16.40	RAF
05/27/83	1140	Olympic Probe	16.40	RAF
05/28/83	1505	Olympic Probe	16.39	RAF
05/29/83	1520	Olympic Probe	16.39	RAF
05/30/83	1815	Olympic Probe	16.37	RAF
05/31/83	1245	Olympic Probe	16.35	RAF
06/01/83	1725	Olympic Probe	16.37	RAF
06/02/83	0720	Olympic Probe	16.38	RAF

WELL 20/52-18

Date	Time	Measuring Device	Reading	Taken By
05/07/83	2005	Olympic Probe	4.20	RAF
05/08/83	1920	Olympic Probe	4.21	RAF
05/09/83	1605	Olympic Probe	4.22	RAF
05/10/83	1915	Olympic Probe	4.23	RAF
05/11/83	1645	Olympic Probe	4.23	RAF
05/23/83	2045	Olympic Probe	4.27	RAF
05/25/83	1010	Olympic Probe	4.28	RAF
05/26/83	0905	Olympic Probe	4.25	RAF
05/27/83	1145	Olympic Probe	4.24	RAF
05/28/83	1510	Olympic Probe	4.25	RAF
05/29/83	1525	Olympic Probe	4.20	RAF
05/30/83	1855	Olympic Probe	4.21	RAF
05/31/83	1250	Olympic Probe	4.20	RAF
06/01/83	1720	Olympic Probe	4.23	RAF
06/02/83	0725	Olympic Probe	4.21	RAF

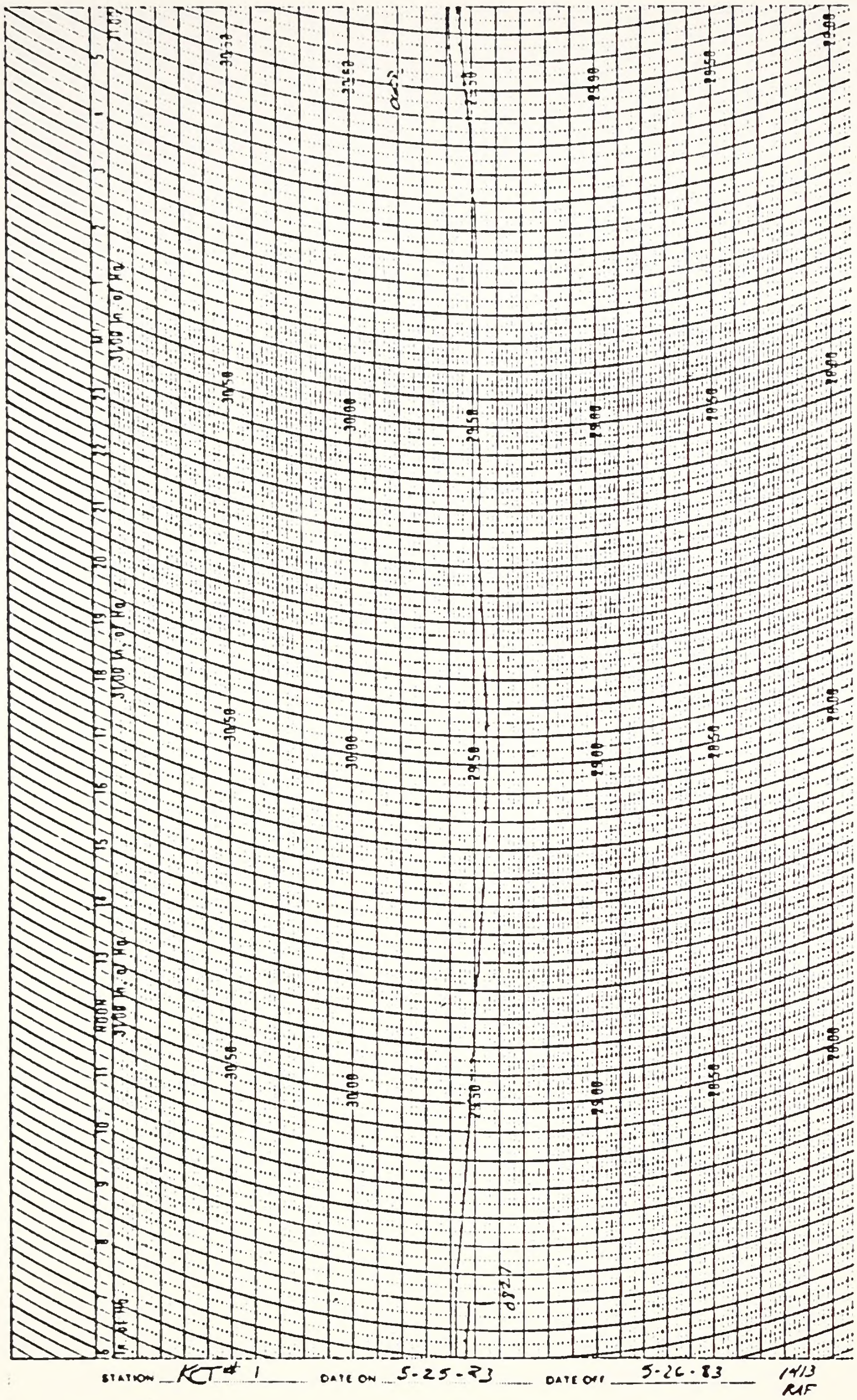
MISCELLANEOUS WATER LEVEL MEASUREMENTS

TAKEN DURING PUMP TEST

WELL MX KB-(0)-1(59)

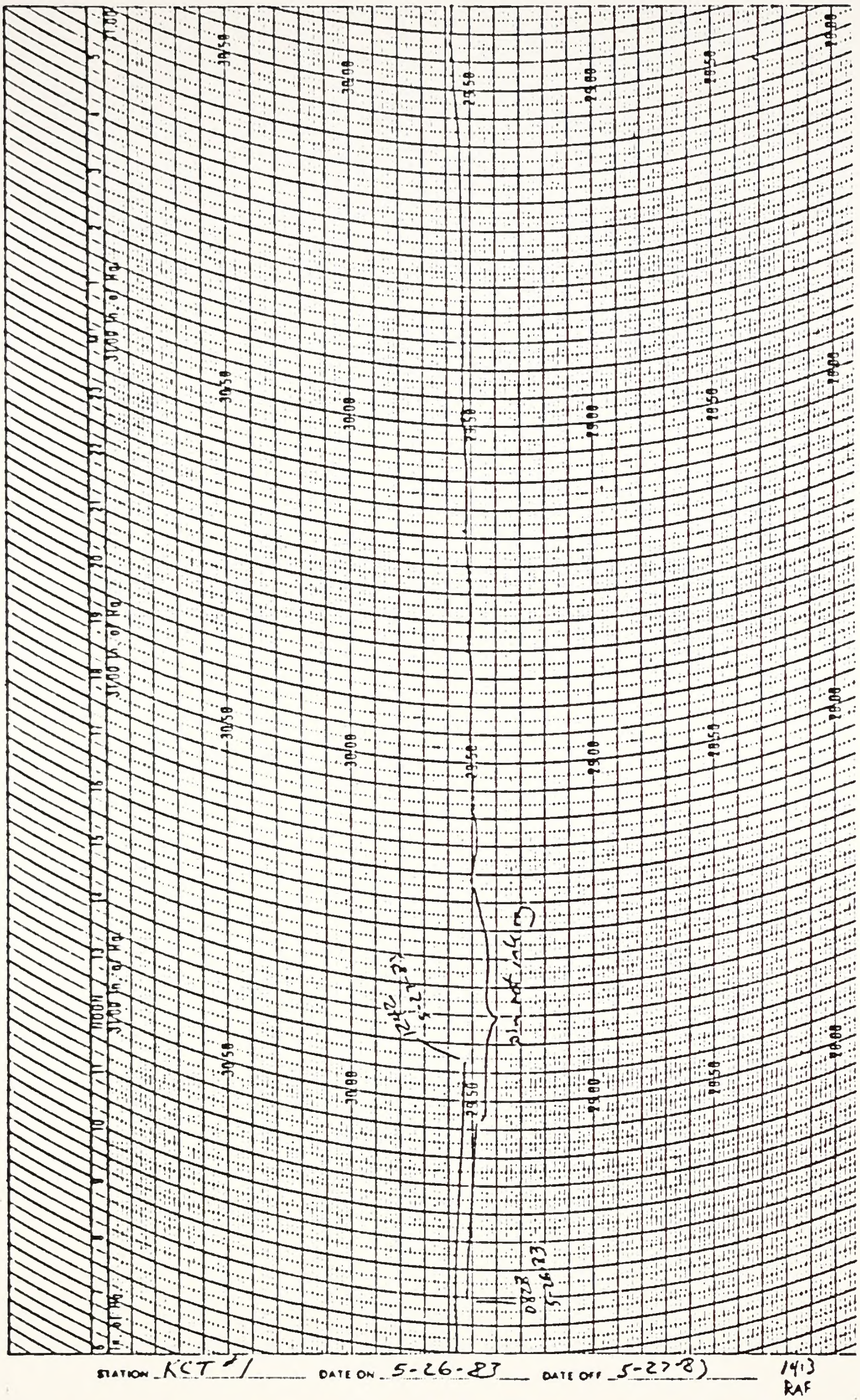
Date	Time	Measuring Device	Reading	Taken By
05/07/83	1955	Olympic Probe	39.86	RAF
05/08/83	1915	Olympic Probe	39.70	RAF
05/09/83	1610	Olympic Probe	39.74	RAF
05/10/83	1750	Olympic Probe	39.73	RAF
05/11/83	1425	Olympic Probe	39.76	RAF
05/23/83	2100	Olympic Probe	39.71	RAF
05/25/83	1015	Olympic Probe	39.67	RAF
05/26/83	0915	Olympic Probe	39.70	RAF
05/27/83	1155	Olympic Probe	39.72	RAF
05/28/83	1520	Olympic Probe	39.71	RAF
05/29/83	1535	Olympic Probe	39.73	RAF
05/30/83	1040	Olympic Probe	39.71	RAF
05/30/83	1900	Olympic Probe	39.68	RAF
05/31/83	1255	Olympic Probe	39.67	RAF
06/01/83	1500	Olympic Probe	39.66	RAF
06/02/83	0735	Olympic Probe	39.70	RAF

Microbarograph Chart during Constant Discharge Test at KCT #1.



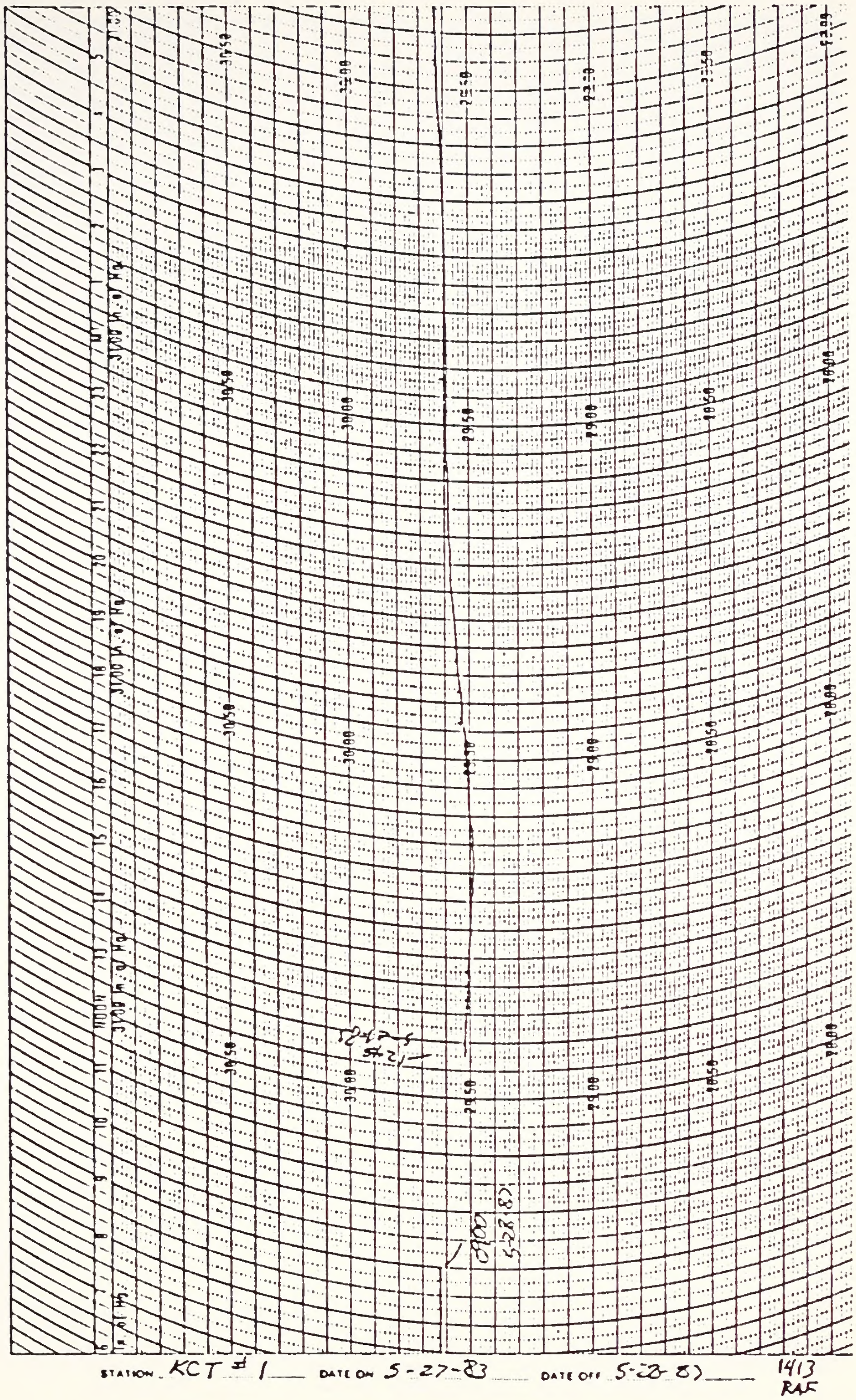
Note: Relative readings only; not calibrated to actual atmospheric pressure.

Microbarograph Chart during Constant Discharge Test at KCT #1.



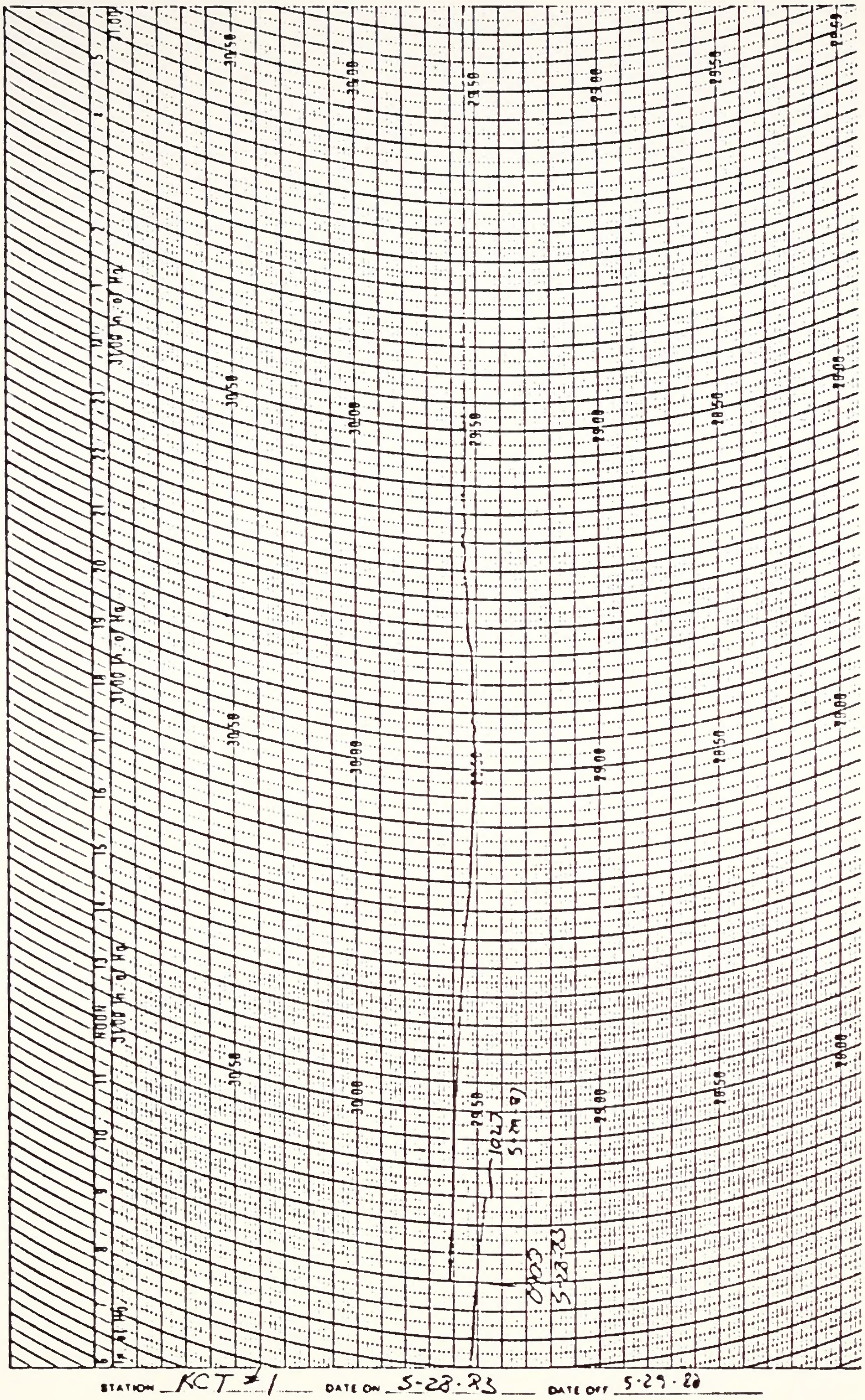
Note: Relative readings only; not calibrated to actual atmospheric pressure.

Microbarograph Chart during Constant Discharge Test at KCT #1.



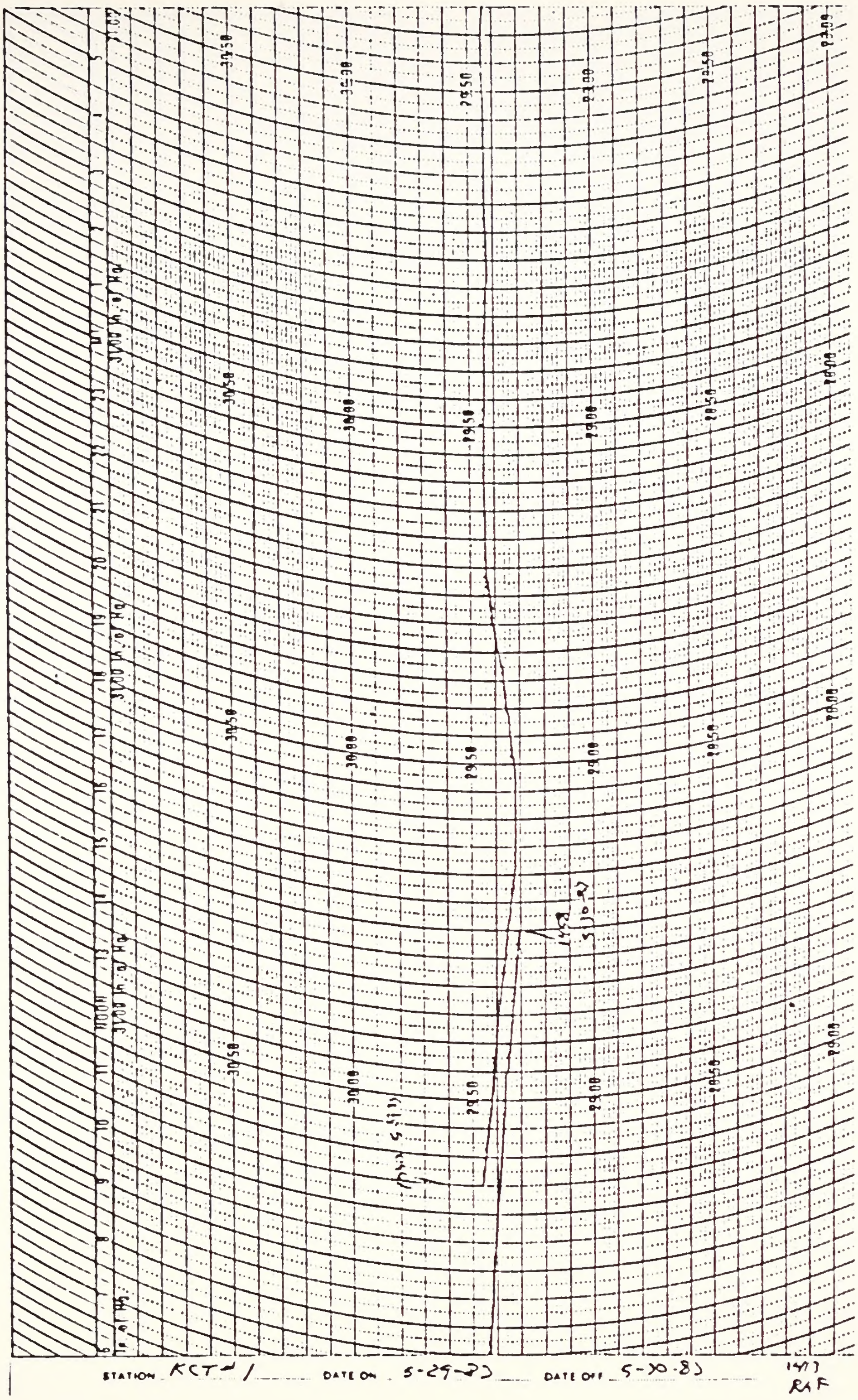
Note: Relative readings only; not calibrated to actual atmospheric pressure.

Microbarograph Chart during Constant Discharge Test at KCT #1.



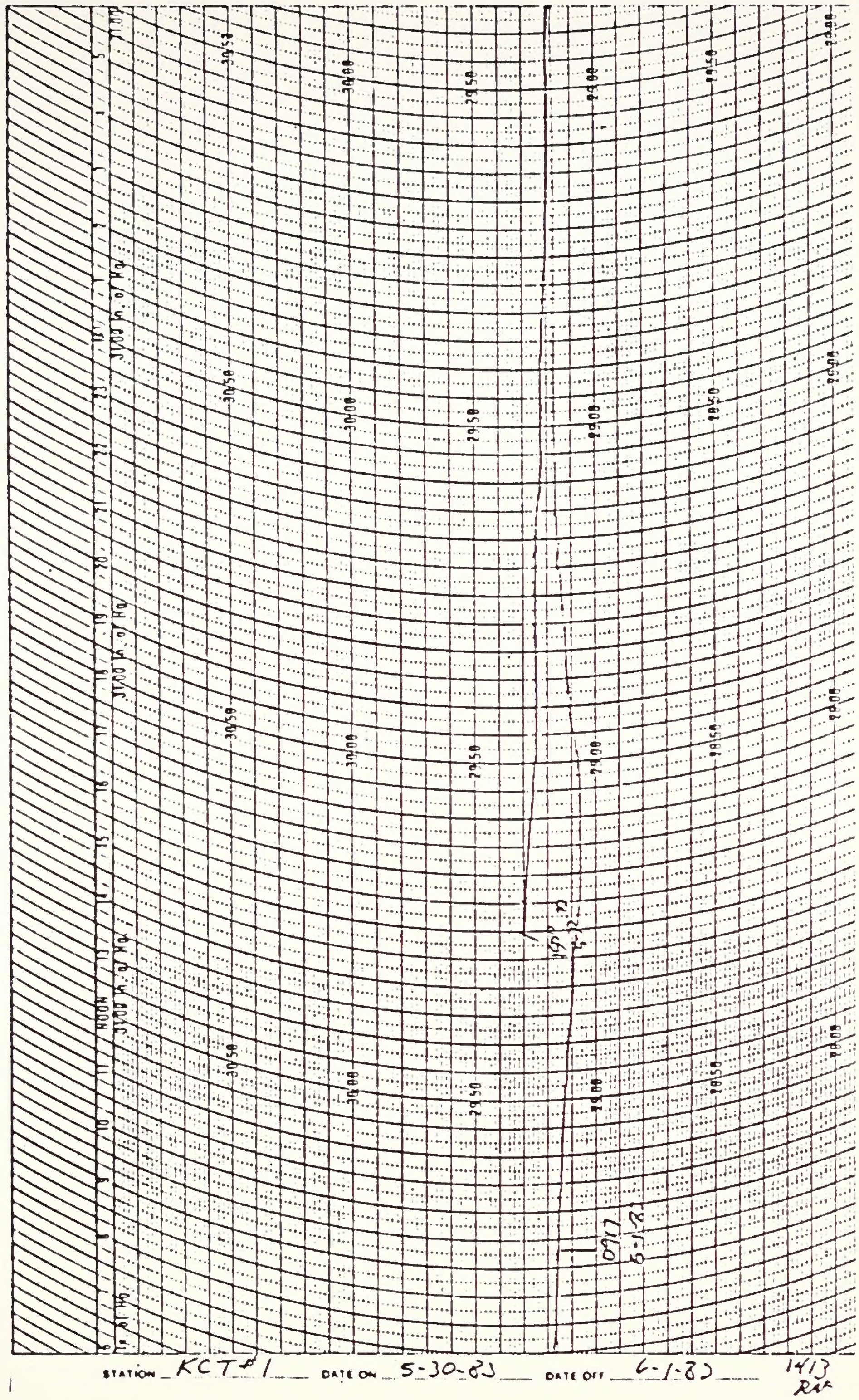
Note: Relative readings only; not calibrated to actual atmospheric pressure.

Microbarograph Chart during Constant Discharge Test at KCT #1.



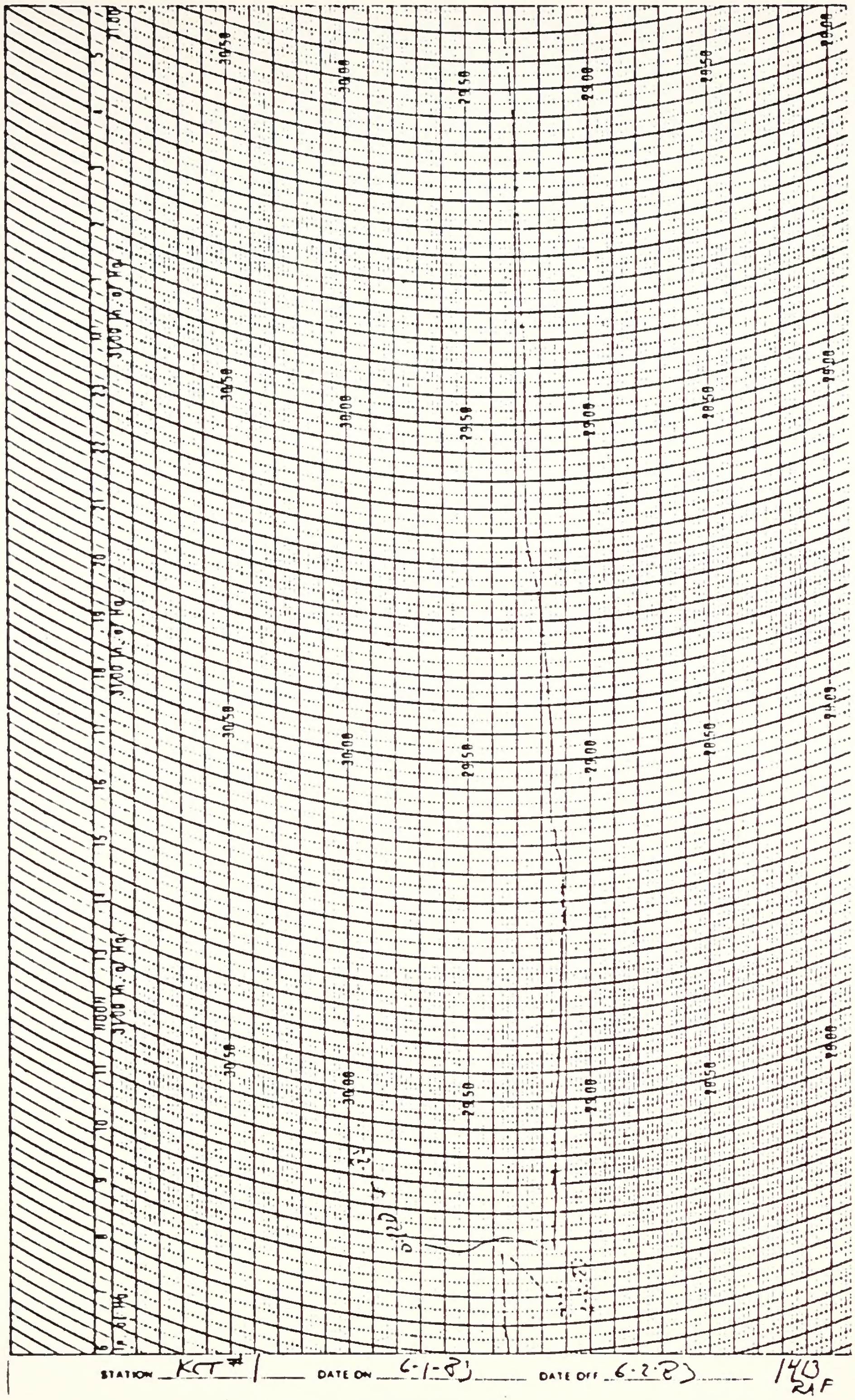
Note: Relative readings only; not calibrated to actual atmospheric pressure.

Microbarograph Chart during Constant Discharge Test at KCT #1.



Note: Relative readings only; not calibrated to actual atmospheric pressure.

Microbarograph Chart during Constant Discharge Test at KCT #1.



Note: Relative readings only; not calibrated to actual atmospheric pressure.

APPENDIX 4-F

STORM RUNOFF, FLOODPLAIN

and HYDROGRAPH CALCULATIONS

100-YEAR STORM RUNOFF AND HYDROGRAPH CALCULATIONS

Storm runoff and routed storm hydrographs were calculated by HYMO, a computer model based on the SCS method of estimating rainfall runoff for small ungaged watersheds. The Fortran IV code for the model and basic procedures for estimating the parameters and input data required by HYMO are outlined in HYMO: Problem-Oriented Computer Language for Hydrologic Modeling, (Williams and Hann, 1972).

Estimation of Storm Runoff

The method of estimation of the 100-year, 6-hour and 24-hour precipitation events was the same as described in the Phase I report. The magnitude of the precipitation events was also the same; however, the incremental precipitation values were modified to accommodate smaller discrete time intervals (Δt = 0.25 hours).

HYMO performs all the calculations prescribed by the SCS method, using the same soil-cover parameters. Minor changes in the values of some of the parameters were made as a result of the field reconnaissance. The values of the soil-cover parameters for each watershed or sub-watershed were verified or modified and are shown in Table A-1.

HYMO calculates storm runoff hydrographs using unit hydrograph methods. Design storm runoff hydrographs for each watershed or sub-watershed were computed and are shown in Table A-1.

Estimation of Routed Runoff Hydrographs

HYMO routes the storm runoff through the watersheds and sub-watersheds using the Variable Travel Time (VTT) flood-routing method (Williams, 1975) resulting in storm runoff hydrographs at specified locations within the watersheds.

Stream channel cross sections and hydraulic gradients were measured (Figures A-1 through A-6), and roughness coefficients were estimated (Chow, 1959) during field reconnaissance. Parameters for calculation of flow rating curves for stream channel cross sections are shown in Table A-2. Flood routing parameters were estimated from topographic maps for various reaches of the stream channels and are shown in Table A-3.

Flow rating curves and routing travel time tables were computed by HYMO. HYMO routes storm runoff hydrographs from each watershed downstream where it is combined with other routed runoff hydrographs by using the curves and tables. The final result is routed runoff hydrographs for each stream channel cross section for the design storms (Figures A-7 through A-17). The estimated water surface elevation at each stream channel cross section for peak flow of the 100-year, 24-hour event is shown in Figures A-1 through A-6. Results from the Routed storm runoff hydrographs are shown in Table 2 and Plate I.

Table A-1. Watershed Parameters for Runoff Hydrograph Estimation using SCS Method (HYMO).

Watershed	Drainage Area ac.(ha)	Watershed Length mi.(km)	Elevation Change ft.(m)	Hydrologic Soil Group	Vegetation Type	Principal Vegetation Density	Antecedent Moisture Condition	Runoff Curve Number
Upper Garden Pass Creek (North)	503 (203.7)	1.40 (2.25)	344 (105)	B	sage-grass	30%	III	78
Upper Garden Pass Creek (West)	1374 (556.5)	2.73 (4.40)	1820 (555)	B/C	sage-grass	30%	III	84
Central Garden Pass Creek	4222 (1709.9)	4.20 (6.76)	1385 (422)	D/B	juniper-sage-grass	30%	III	88
Upper Tyrone Creek	449 (181.8)	1.82 (2.93)	900 (274)	D/C	juniper-grass	30%	III	94
Lower Tyrone Creek	3824 (1548.7)	4.09 (6.58)	1609 (491)	D	juniper-sage-grass	30%	III	93
Lower Garden Pass Creek	1923 (778.8)	2.61 (4.20)	835 (255)	D	juniper-sage-grass	30%	III	94
Upper Northeast Kobeh Valley #1	1643 (665.4)	2.08 (3.35)	546 (167)	C	juniper-grass	30%	III	89
Lower Northeast Kobeh Valley #1	1596 (646.4)	3.18 (5.12)	1821 (555)	C	juniper-grass	30%	III	88
Upper Northeast Kobeh Valley #2	699 (283.1)	1.70 (2.74)	747 (228)	C	juniper-grass	30%	III	91

Table A-2. Parameters for Calulation of Flow-Rating Curves for Stream Channel Cross Sections.

Stream Channel Cross Sections	Ground Level Elevation ft.(m)	Channel Bottom Elevation ft.(m)	Channel Slope ft/ft-m/m	Flood Plain Slope ft/ft-m/m	Manning's Roughness Coefficient, n	
					Channel	Flood Plain
1-Upper Garden Pass Creek (North)	6537 (1994)	6532.2 (1992)	0.0210	0.0323	0.060	0.070
2-Upper Garden Pass Creek (west)	6539 (1994)	6533.5 (1993)	0.0285	0.0342	0.050	0.065
3-Upper Garden Pass Creek	6534 (1993)	6528.1 (1991)	0.0203	0.0332	0.040	0.060
4-Upper Central Garden Pass Creek	6113 (1864)	6108.8 (1863)	0.0108	0.0250	0.050	0.070
5-Upper Tyrone Creek	6510 (1986)	6507.2 (1985)	0.0470	0.0500	0.045	0.070 & 0.080
6-Lower Tyrone Creek	6111 (1864)	6105.9 (1862)	0.0090	0.0230	0.035	0.060
7-Central Garden Pass Creek	6107 (1863)	6101.7 (1861)	0.0104	0.0240	0.035	0.060
8-Lower Garden Pass Creek	6005 (1832)	6001.2 (1830)	0.0083	0.0180	0.040	0.060 & 0.070
9-Upper Northeast Kobeh Valley #1	6814 (2078)	6809.4 (2077)	0.0263	0.0286	0.045	0.070
10-Lower Northeast Kobeh Valley #1	6590 (2010)	6585.3 (2009)	0.0130	0.0183	0.020	0.060 & 0.070
11-Upper Northeast Kobeh Valley #2	6613 (2017)	6610.5 (2016)	0.0242	0.0345	0.050	0.070

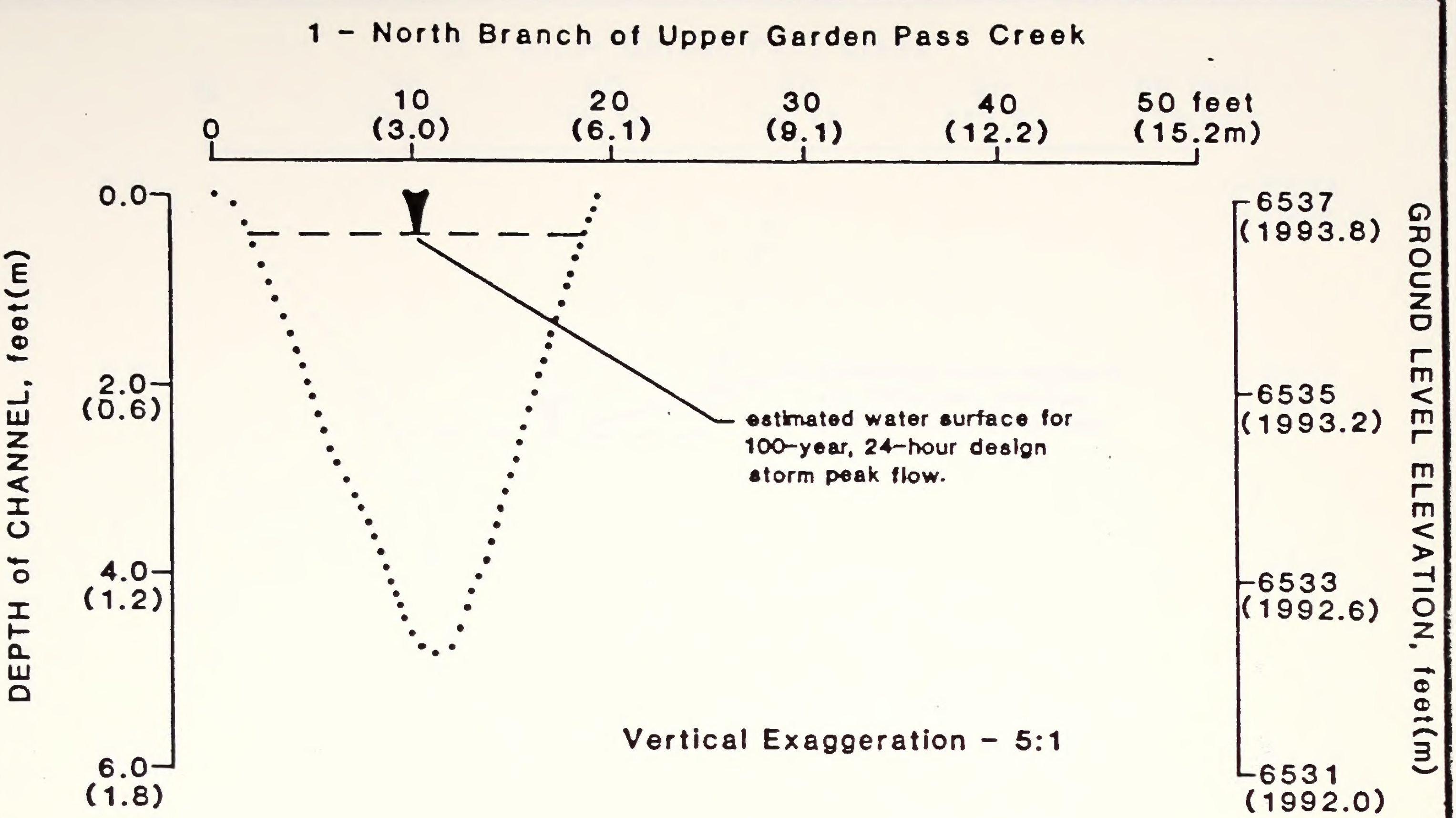
Note: (1) HYMO uses Manning's equation to compute the normal flow-rating curves that are used in the flood routing method.

Table A-3. Parameters for Flood Routing (HYMO)[1].

Stream Reach[2]	Length of Reach ft.(m)	Average Stream Channel Slope ft/ft-m/m
Central Garden Pass Creek (3-4)	17202 (5247)	0.0248
Tyrone Creek (5-6)	14399 (4392)	0.0279
Lower Garden Pass Creek (7-8)	5602 (1709)	0.0179
Northeast Kobeh Valley #1 (9-10)	9800 (2989)	0.0229

Note: (1) HYMO uses Variable Travel Time (VTT) flood-routing method. It includes variation in travel time with stage and water-surface slope in the calculations.

(2) Stream Reach is defined as the stream channel between specified stream channel cross sections (e.g., 3-4 = stream channel between cross sections numbered 3 and 4).



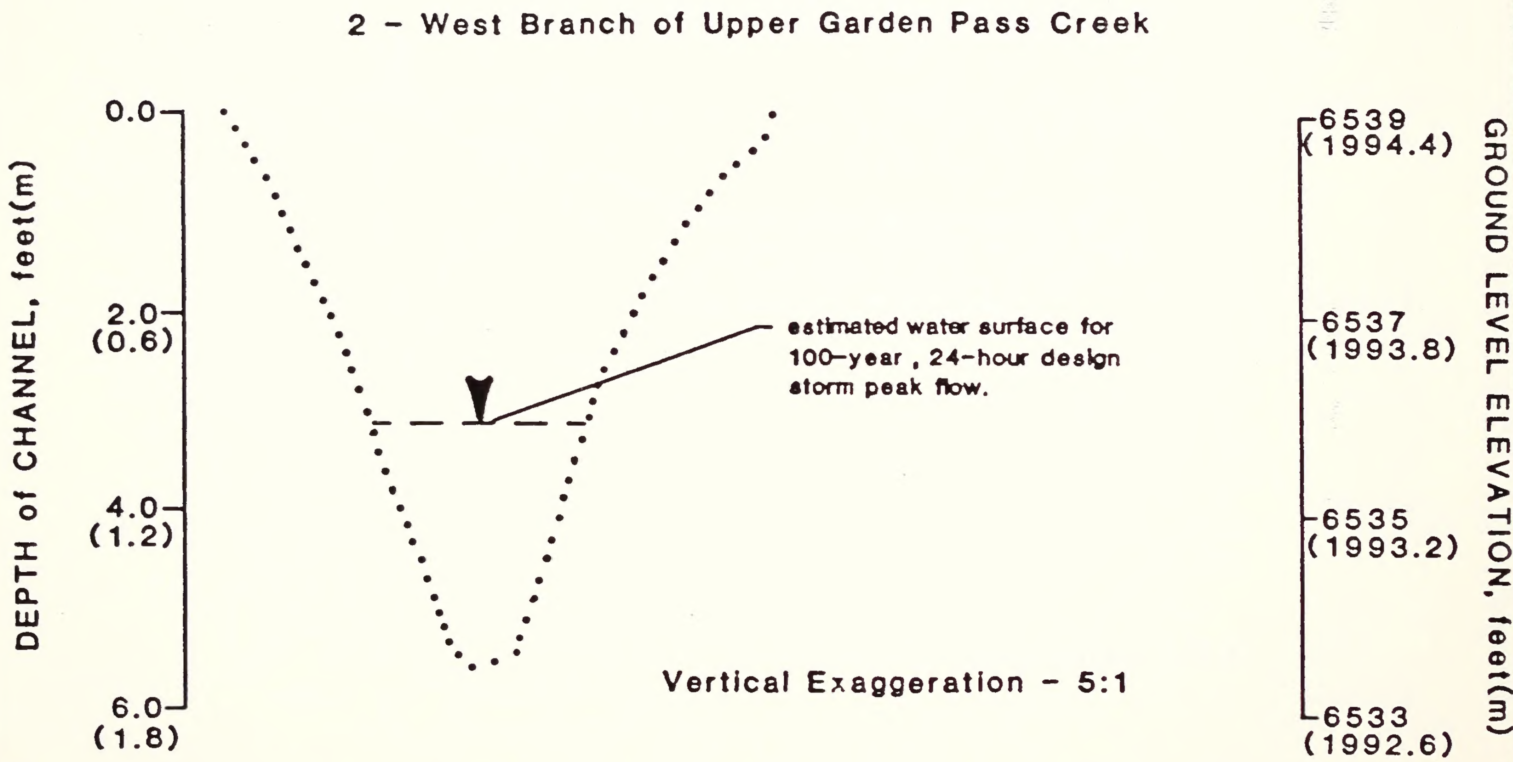


FIGURE A-1. Stream Channel Cross-Sections for Upper Garden Pass Creek.

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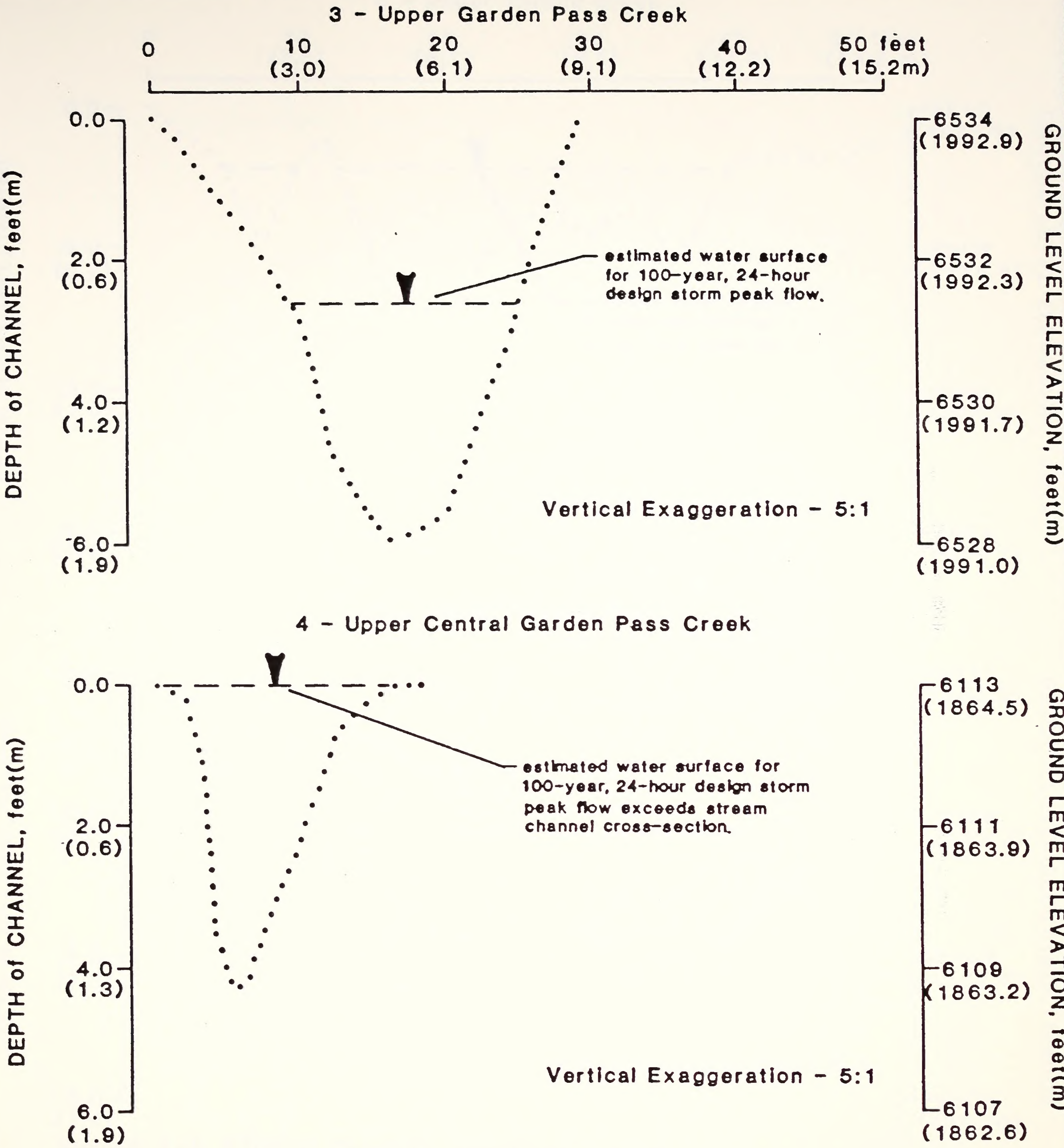

FIGURE A-2. Stream Channel Cross-Section for Central Garden Pass Creek.

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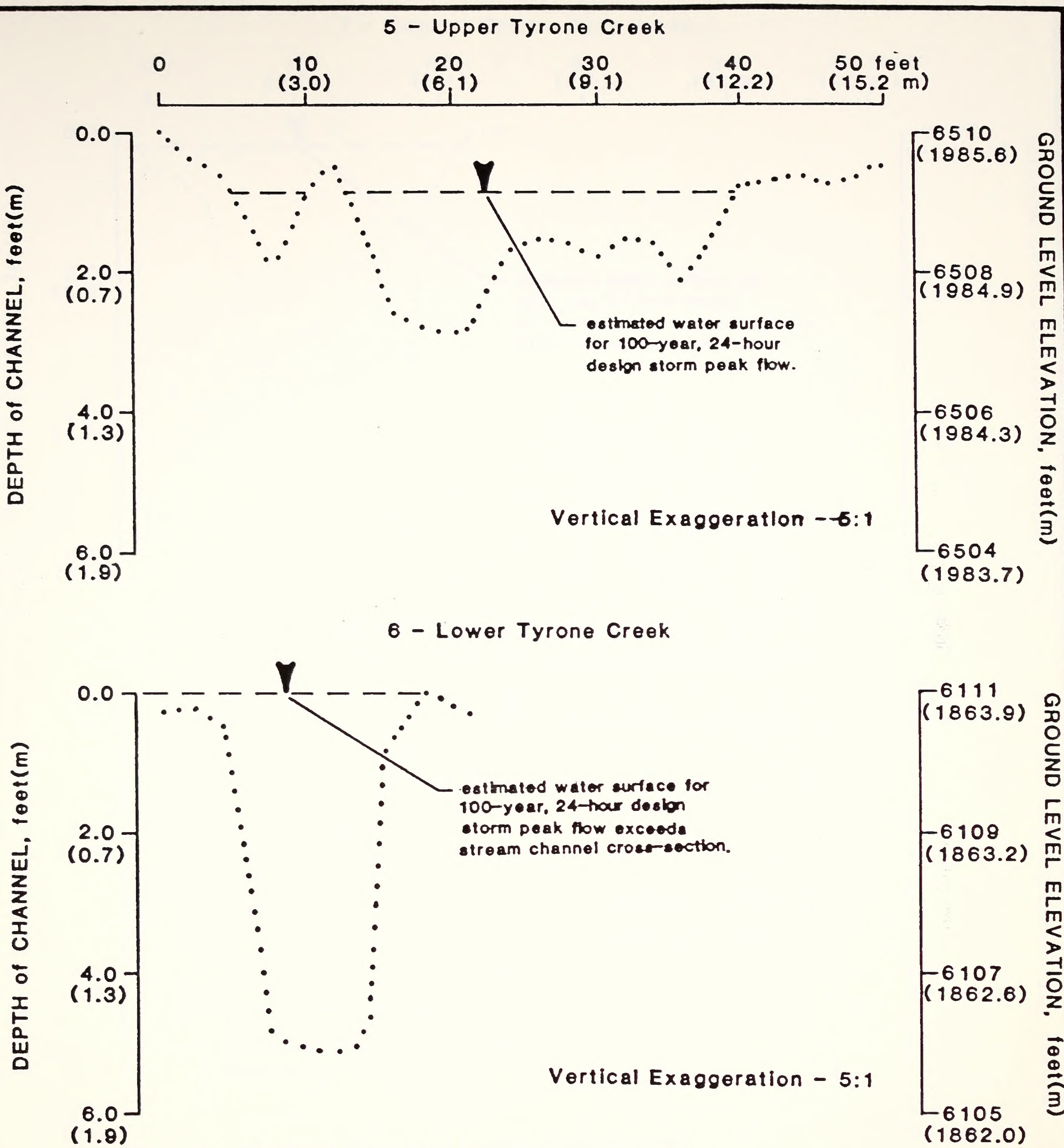

FIGURE A-3. STREAM CHANNEL CROSS-SECTIONS FOR TYRONE CREEK.

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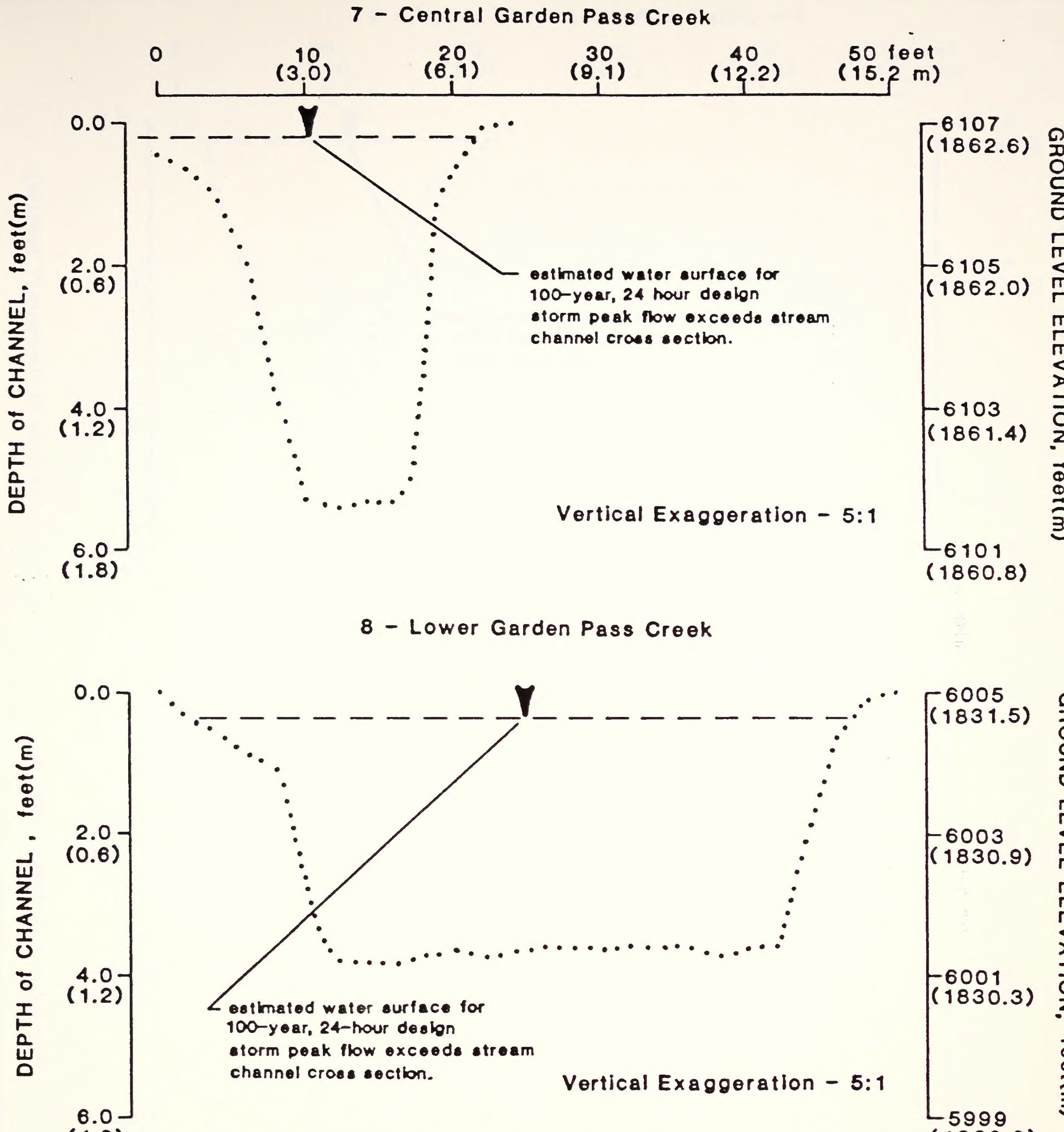

FIGURE A-4. STREAM CHANNEL CROSS-SECTIONS FOR LOWER GARDEN PASS CREEK.

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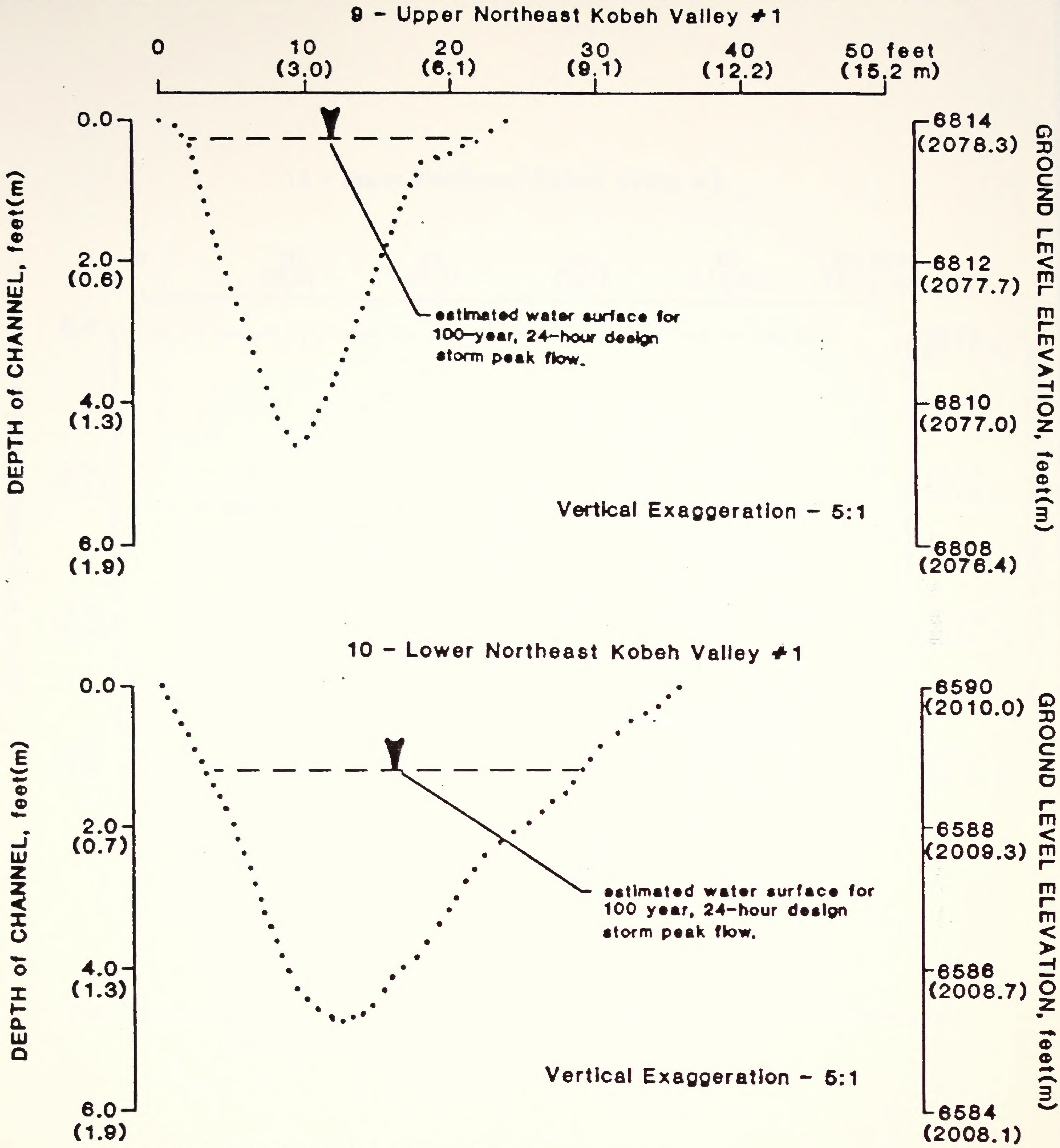

FIGURE A-5. STREAM CHANNEL CROSS-SECTIONS FOR NORTHEAST KOBEH VALLEY #1.

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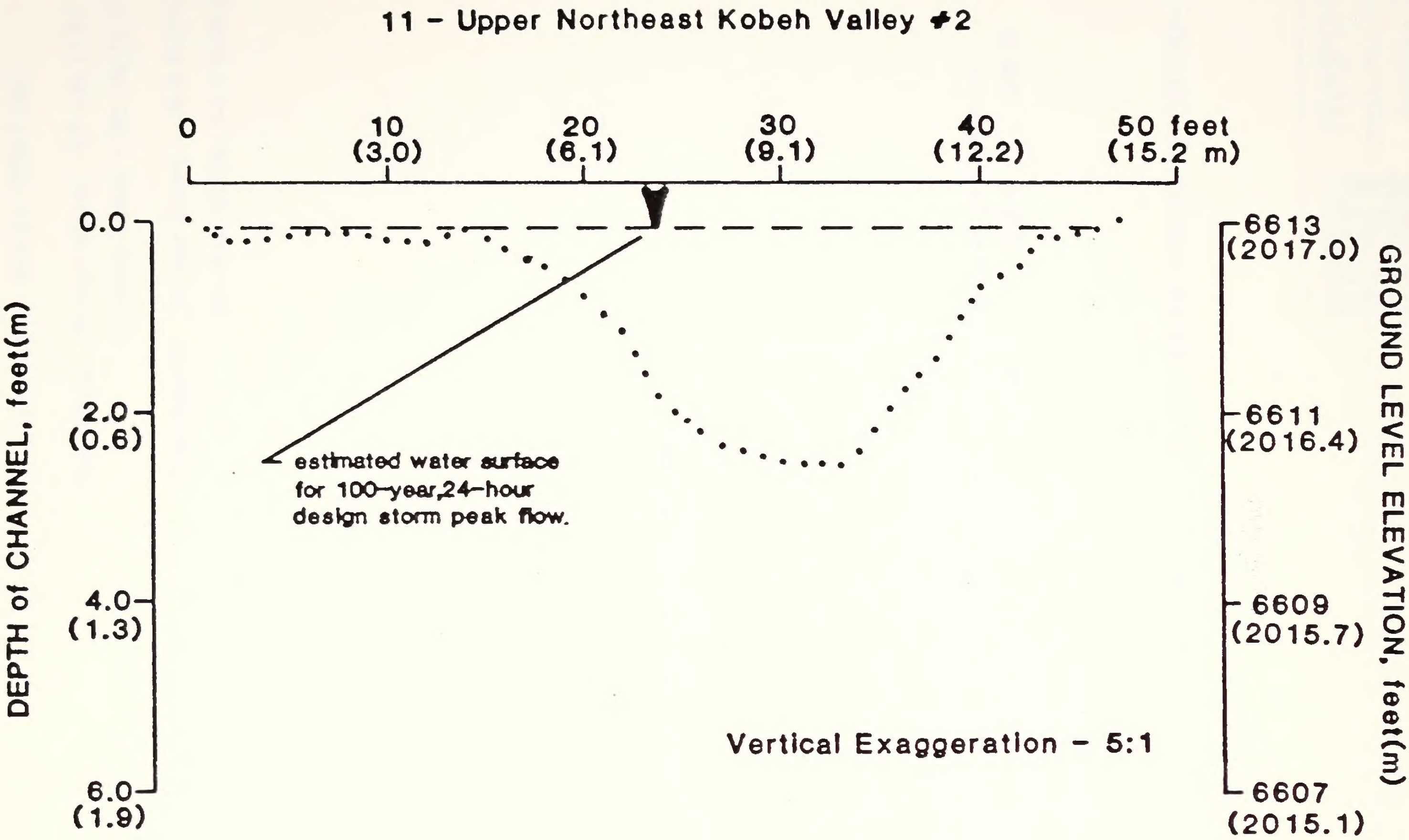

FIGURE A-6. STREAM CHANNEL CROSS-SECTION FOR UPPER NORTHEAST KOBEH VALLEY #2.

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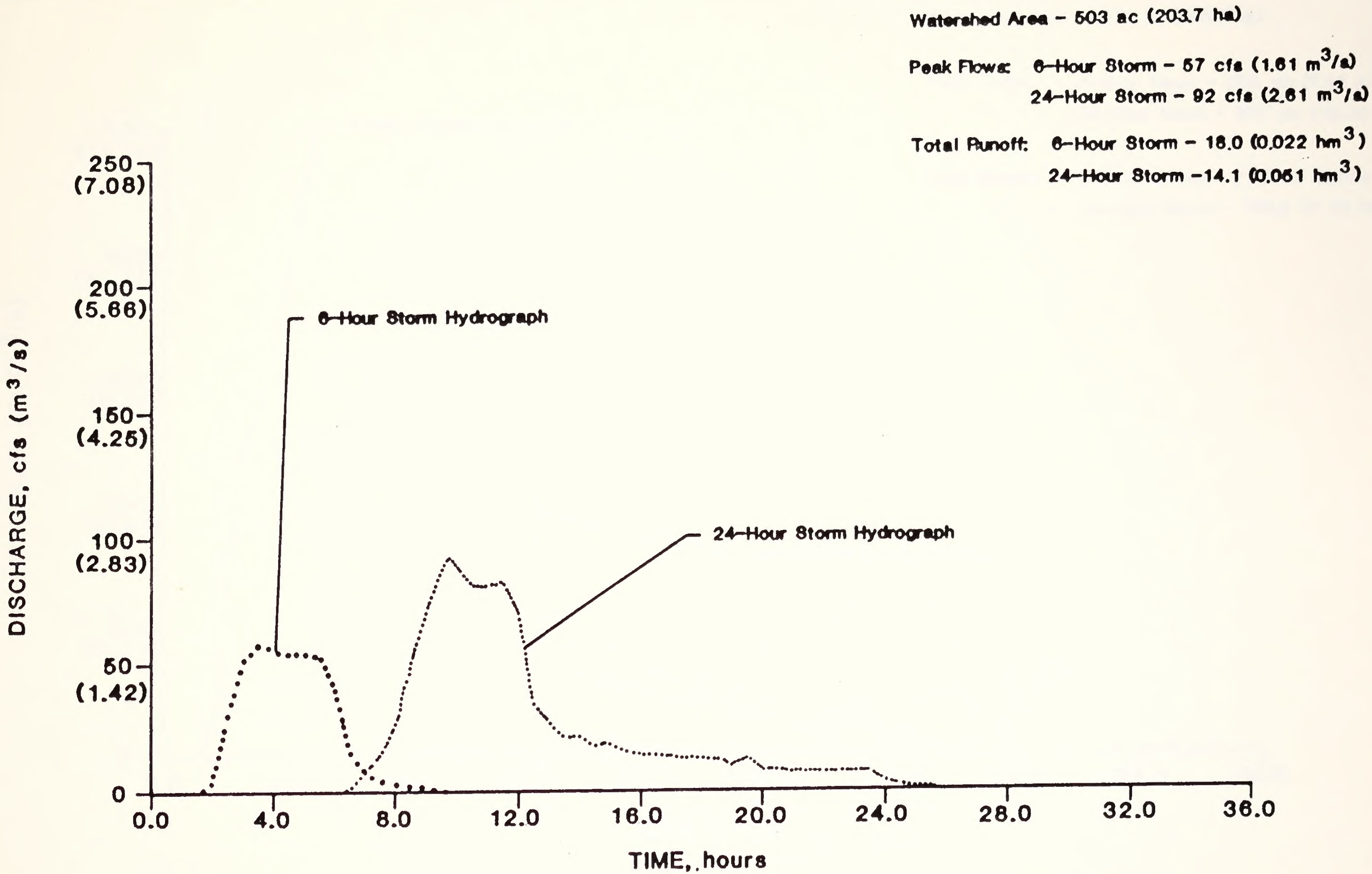

FIGURE A-7. 100-YEAR DESIGN STORM HYDROGRAPHS FOR UPPER GARDEN PASS CREEK (NORTH)-1.

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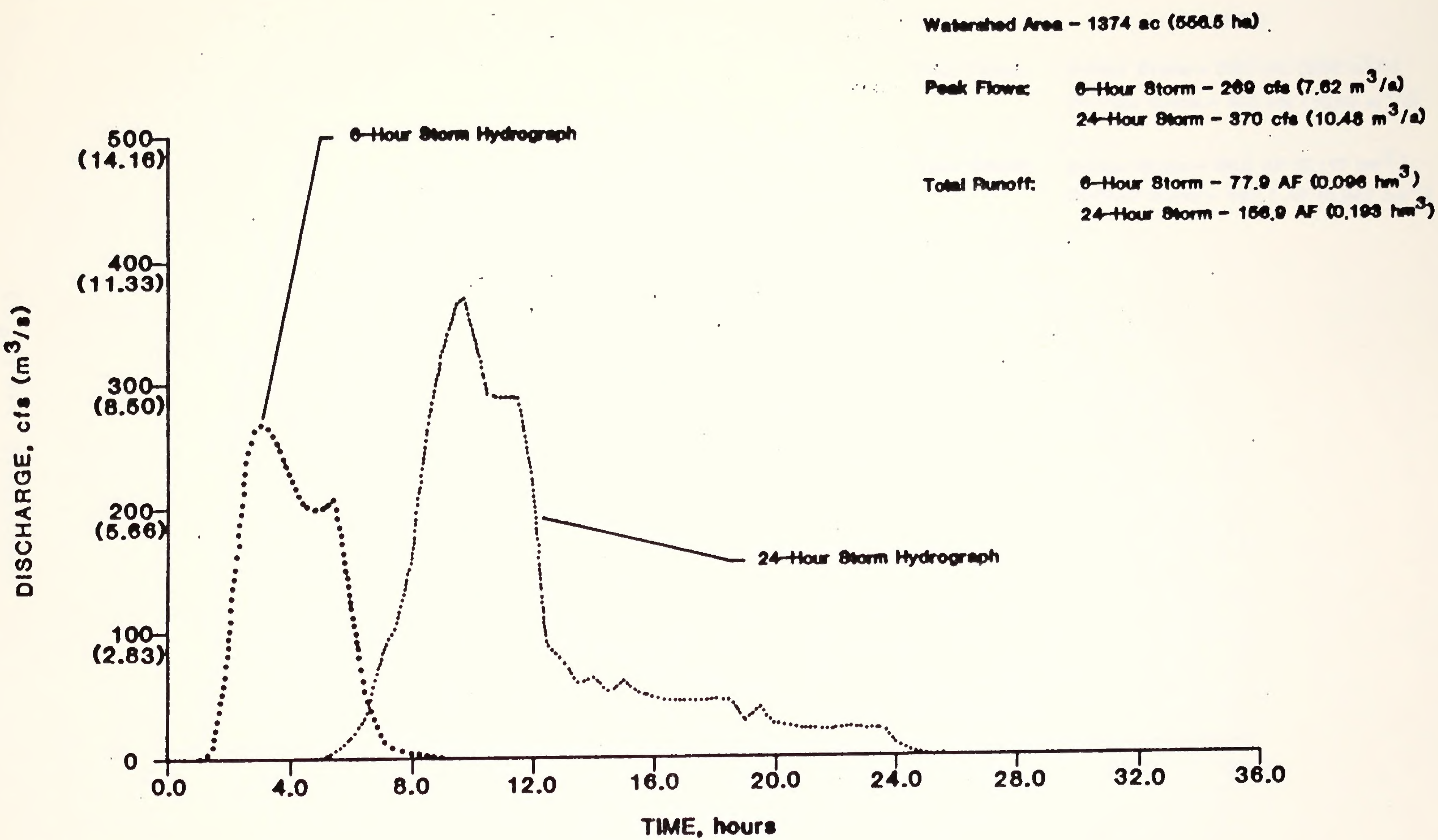

FIGURE A-8. 100-YEAR DESIGN STORM HYDROGRAPHS FOR UPPER GARDEN PASS CREEK (WEST)-2.

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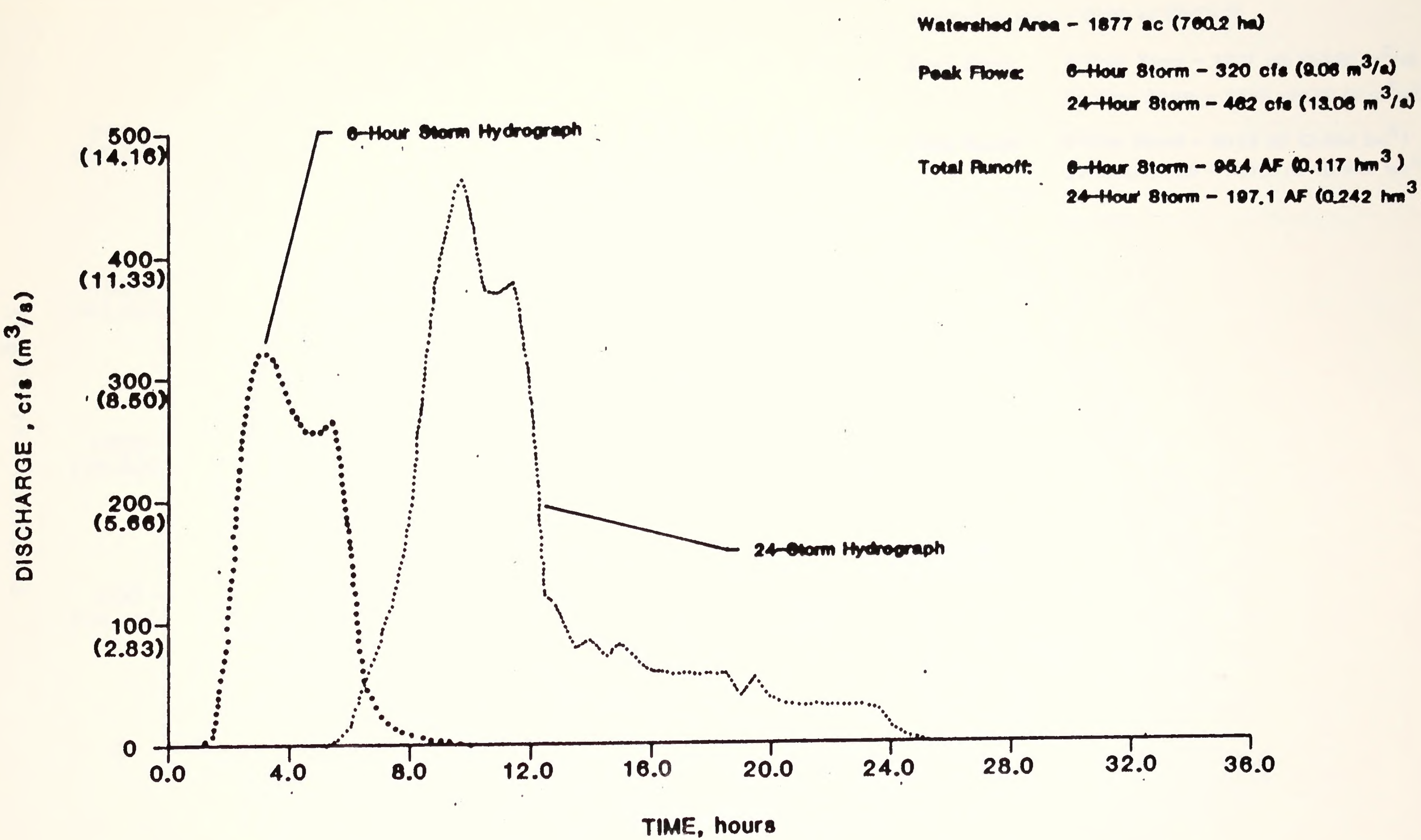

FIGURE A-9. 100-YEAR DESIGN STORM HYDROGRAPHS FOR UPPER GARDEN PASS CREEK - 3.

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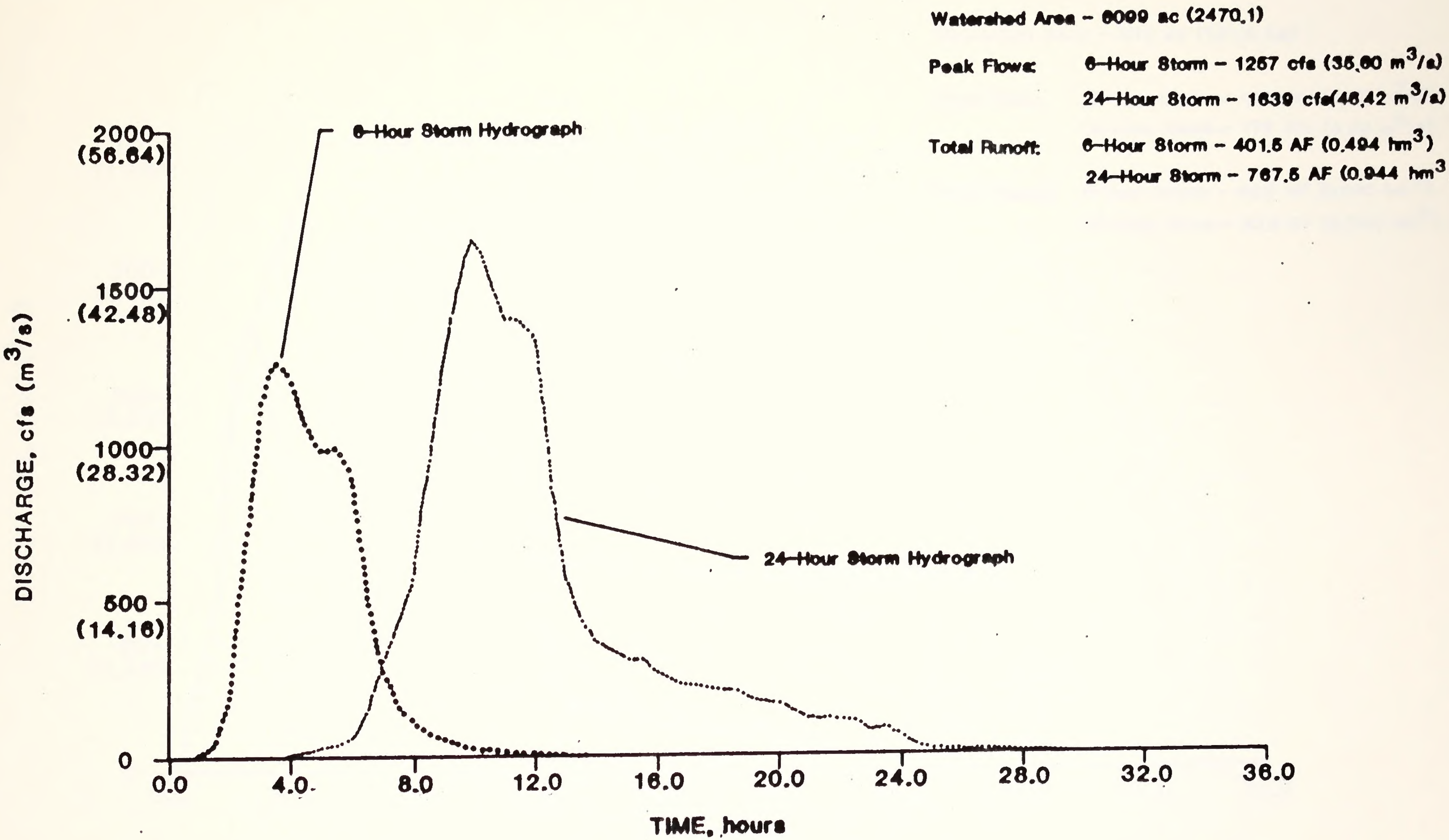

FIGURE A-10. 100-YEAR DESIGN STORM HYDROGRAPHS FOR UPPER CENTRAL GARDEN PASS CREEK - 4.

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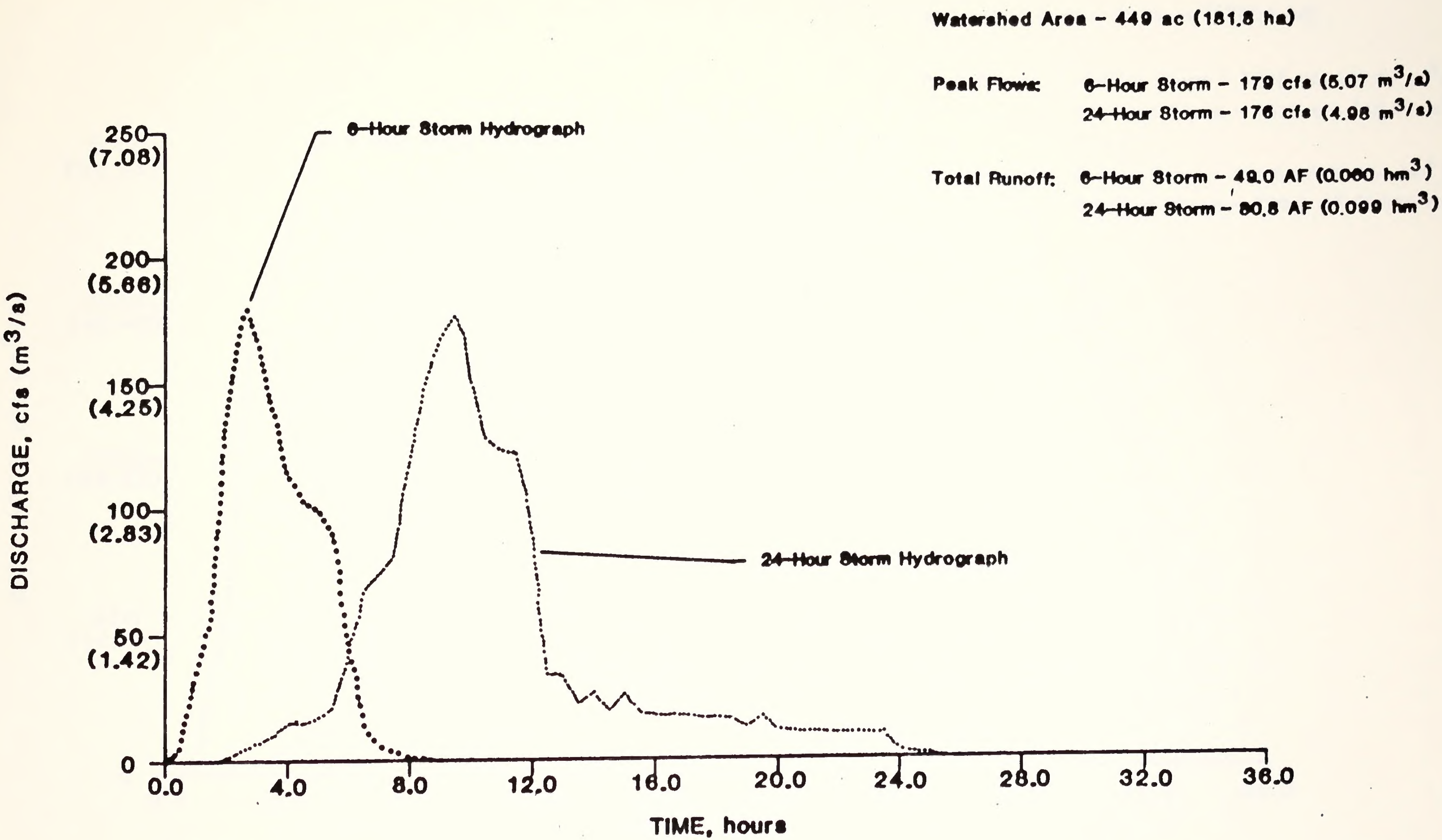

FIGURE A-11. 100-YEAR DESIGN STORM HYDROGRAPHS FOR UPPER TYRONE CREEK - 5.

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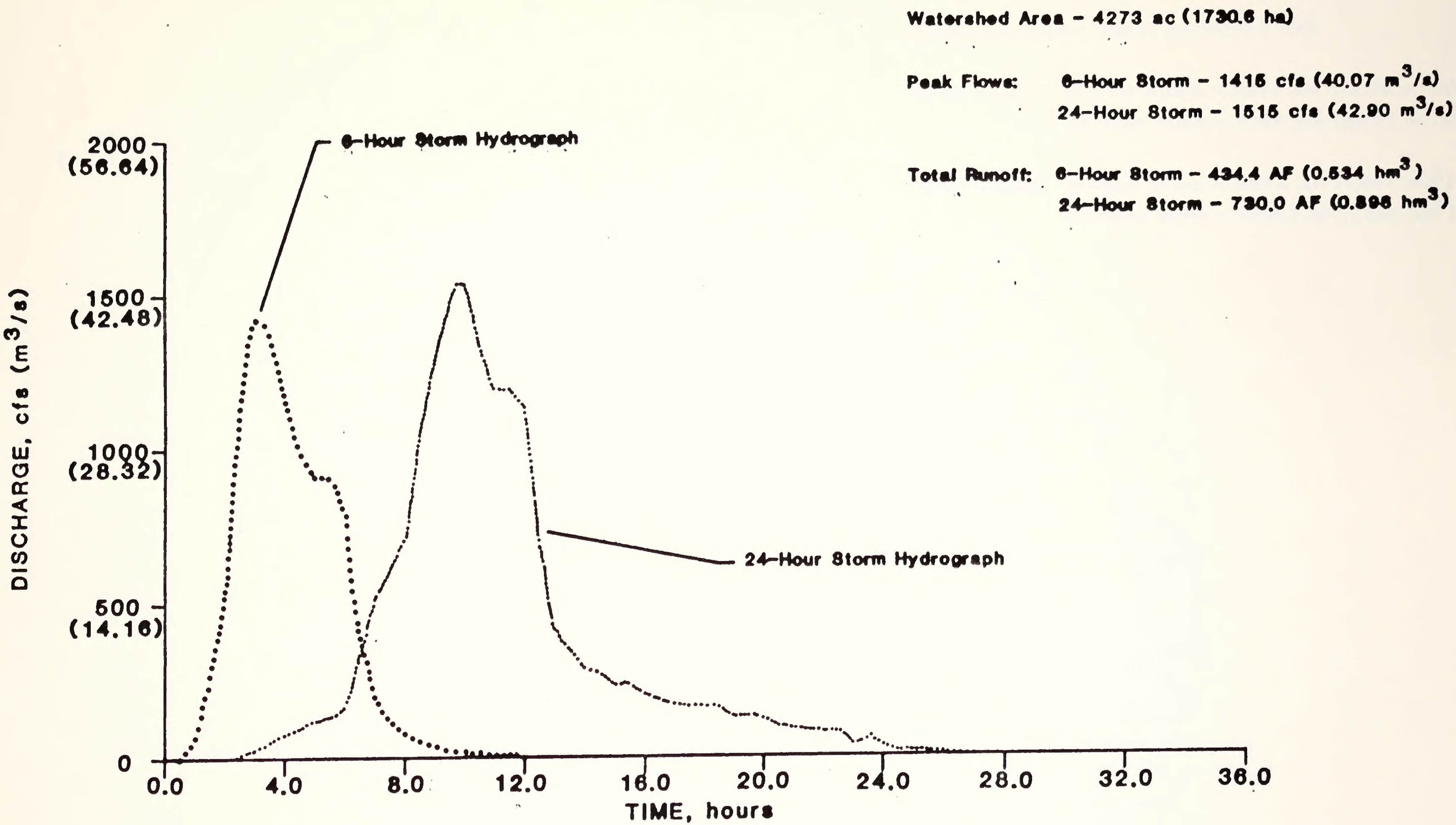

FIGURE A-12. 100-YEAR DESIGN STORM HYDROGRAPHS FOR LOWER TYRONE CREEK - 6.

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Watershed Area – 10372 ac (4200.7 ha)

Peak Flows: 6–Hour Storm – 2634 cfs (74.59 m^3/s)
24–Hour Storm – 3154 cfs (89.32 m^3/s)

Total Runoff: 6–Hour Storm – 838.4 AF (1.031 hm^3)
24–Hour Storm – 1496.3 AF (1.839 hm^3)

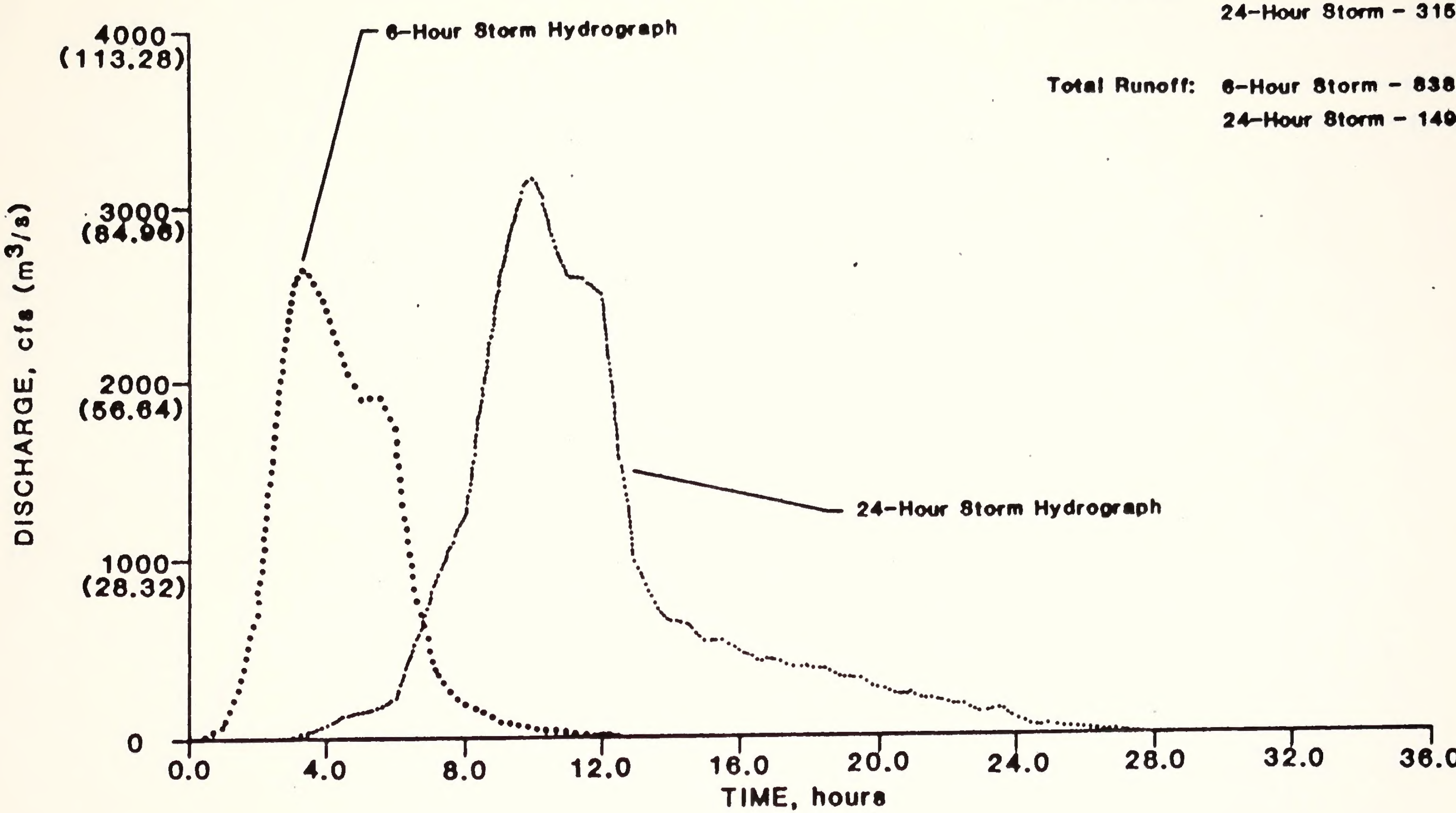

FIGURE A-13. 100-YEAR DESIGN STORM HYDROGRAPHS FOR CENTRAL GARDEN PASS CREEK -7.

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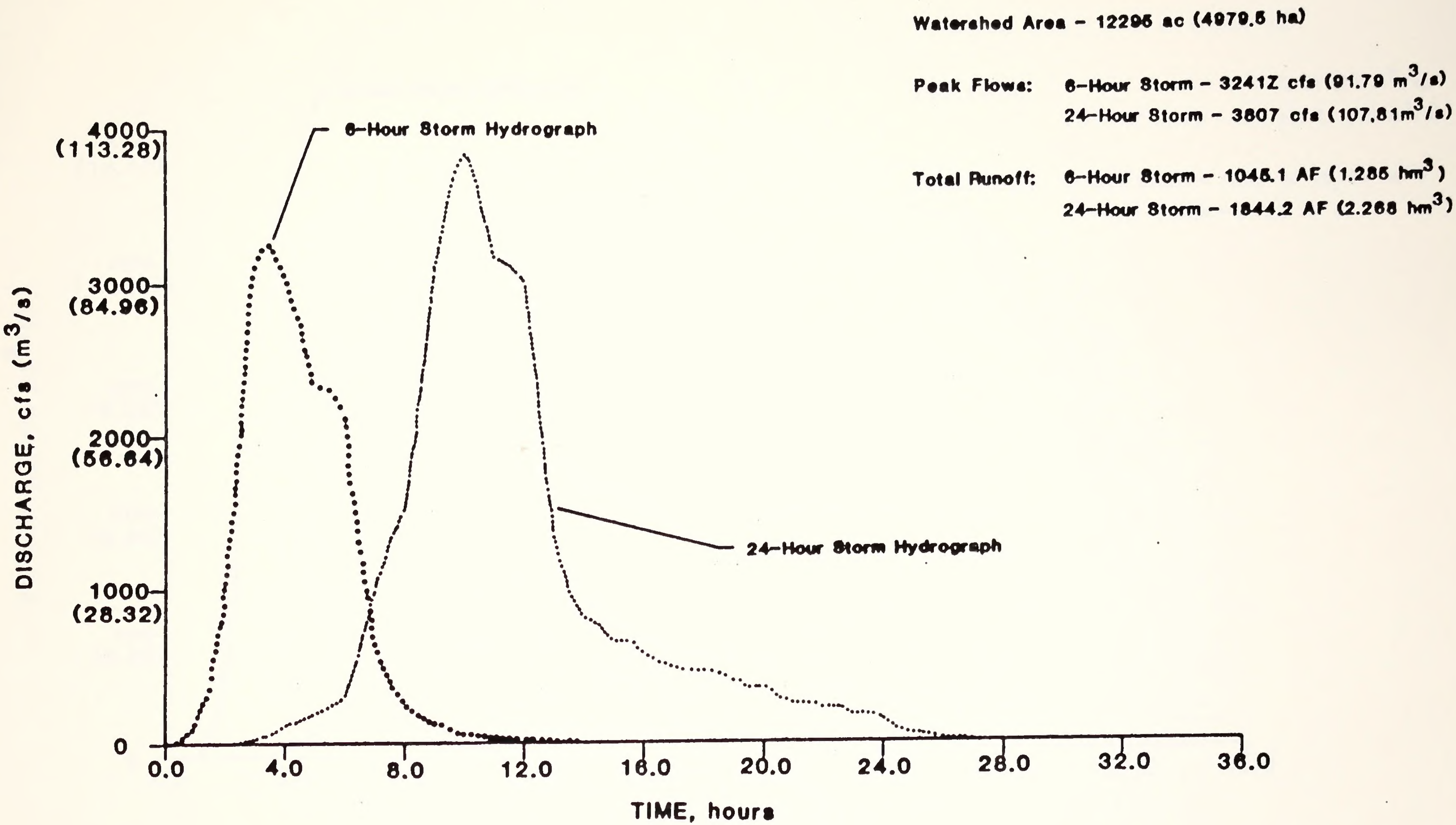

FIGURE A-14. 100-YEAR DESIGN STORM HYDROGRAPHS FOR LOWER GARDEN PASS CREEK - 8.

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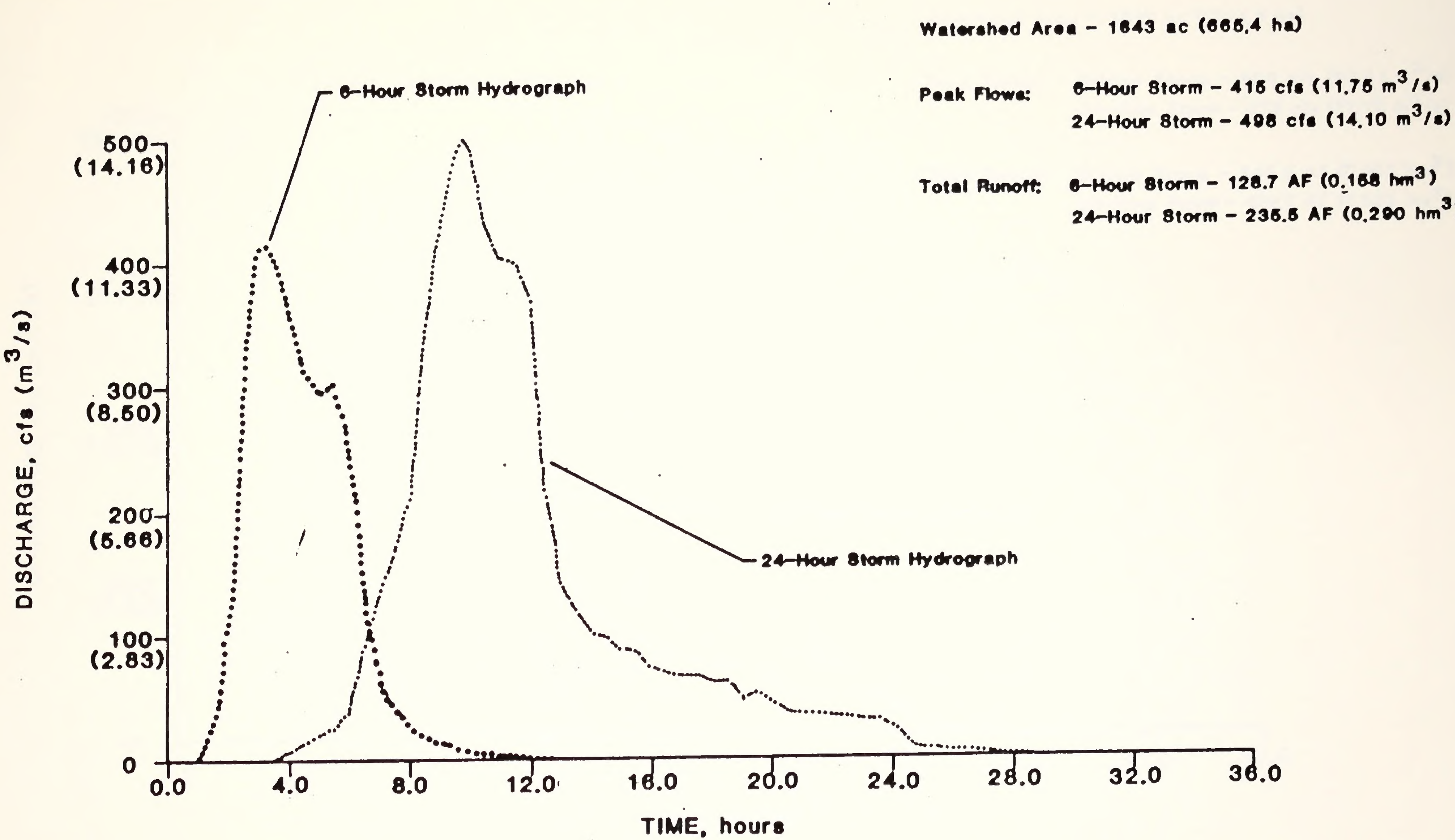

FIGURE A-15. 100-YEAR DESIGN STORM HYDROGRAPHS FOR UPPER NORTHEAST KOBEH VALLEY #1-9.

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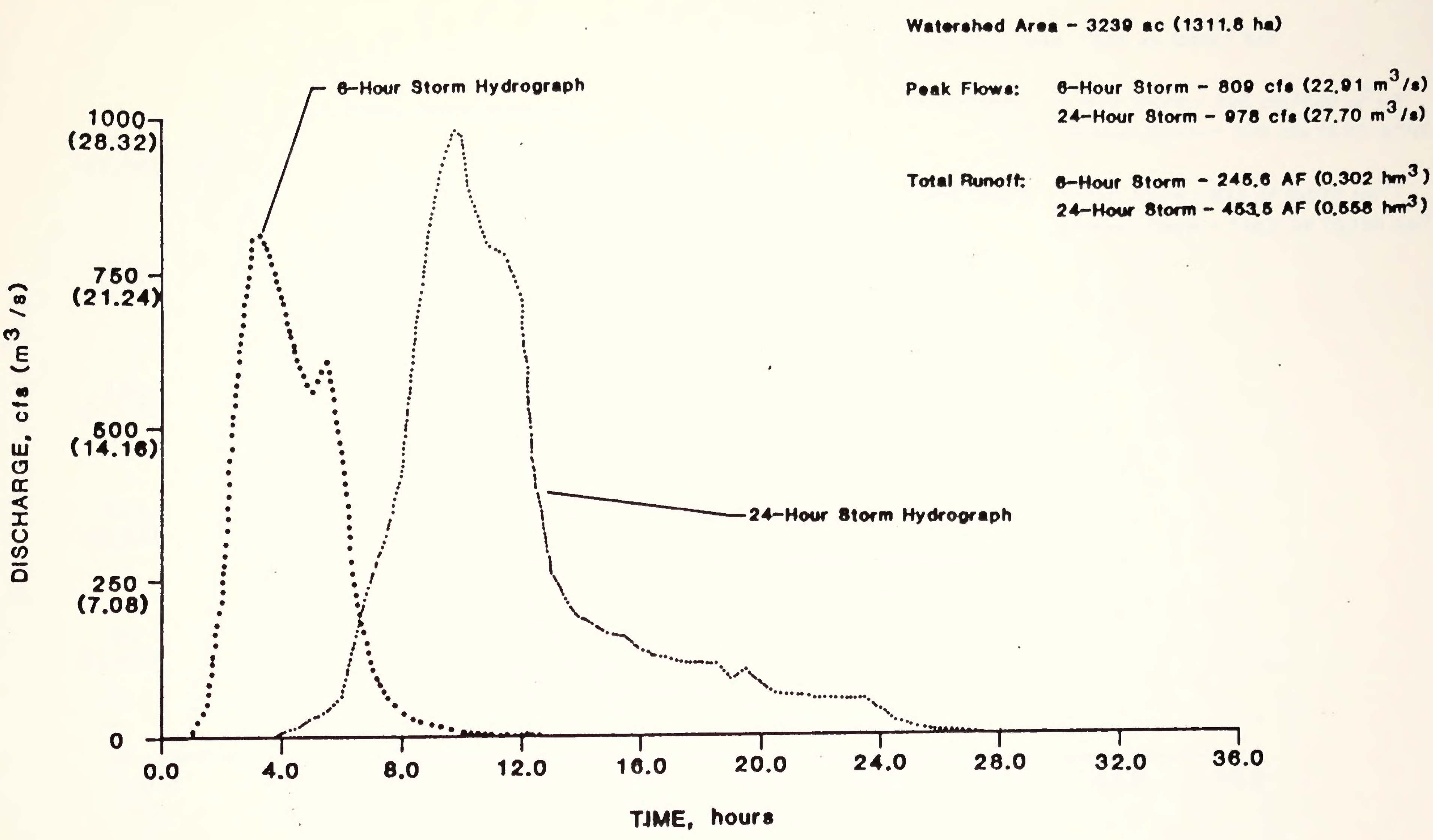

FIGURE A-16. 100-YEAR DESIGN STORM HYDROGRAPHS FOR LOWER NORTHEAST KOBEH VALLEY #1-10.

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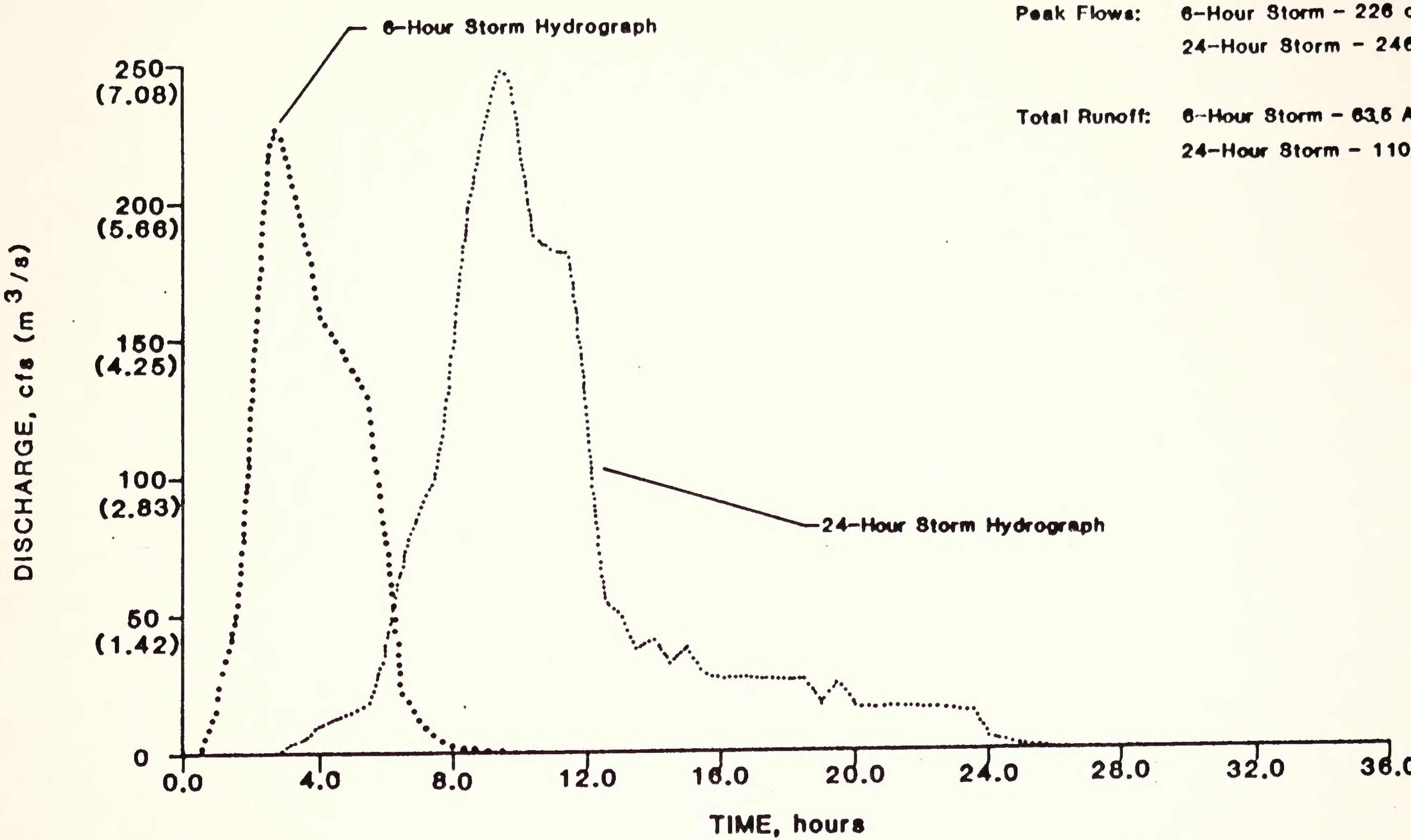

Watershed Area - 699 ac (283.1 ha)

Peak Flows: 6-Hour Storm - 226 cfs (6.40 m^3/s)
24-Hour Storm - 246 cfs (6.97 m^3/s)

Total Runoff: 6-Hour Storm - 63.6 AF (0.078 hm^3)
24-Hour Storm - 110.7 AF (0.136 hm^3)

FIGURE A-17. 100-YEAR DESIGN STORM HYDROGRAPHS FOR UPPER NORTHEAST KOBEH VALLEY #2-11.

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APPENDIX 4-G

MINE WATER INFLOW

CALCULATIONS

MINE WATER INFLOW CALCULATIONS

LATERAL INFLOW (Section 8.1.1)

$$Q = \frac{4\pi T\, s_p}{2.303 \log \dfrac{0.301\, Tt}{r_p^{\,2}\, S}}$$

Jacob-Lohman Equation (Lohman, 1972, p.19)

Q (gallons per day (gpd)) is the discharge to the pit face.

T (gallons per day per foot (gpd/ft)) is the transmissivity of the water-bearing unit and is equal to the hydraulic conductivity, K (gallons per day per foot^2 (gpd/ft^2)), times the thickness of the water-bearing material, b (feet).

The drawdown at the pit face, s_p, is the distance from the original ground-water level, 6400 feet, and the top of the seepage face. The latter is presumed to be halfway between the pit floor and the original ground-water level.

The time in days after the instantaneous imposition of the large diameter well is t.

The effective radius of the seepage face is r_p.

S is the storage coefficient which in this unconfined case can be spoken of as the specific yield.

To convert Q (gpd) to Q (gpm) divide by 1440. To convert Q (gpm) to Q (lps) multiply by 0.0631.

Calculation at 14.2 Years

T ranges from 700 to 70 gpd/ft (igneous complex and Vinini hornfels).

700 gpd/ft = $1.$ gpd/ft^2 x 700 feet (= 6400-5700 feet)

70 gpd/ft = 0.1 gpd/ft^2 x 700 feet

s_p = 350 feet (=6400-6050 feet)

t = 5.8 years x 365 days per year = 2117 days

r_p 1075 feet (effective pit radius at 5875 feet)

S = 0.02 (igneous complex and Vinini hornfels)

Substitution in the Jacob-Lohman equation and conversion of results gives Q ranging from 722 gpm (45.6 lps) to 325 gpm (20.5 lps).

Calculation at 20. Years

T ranges from 1400 to 140 gpd/ft:

1400 gpd/ft = $1.$ gpd/ft^2 x 1400 feet (=6400-5000 feet)

140 gpd/ft = 0.1 gpd/ft^2 x 1400 feet

s_p = 700 feet (=6400-5700 feet)

t = 11.6 years x 365 days per year = 4234 days

r_p 1300 feet (effective pit radius at 5350 feet)

S = as above

Substitution and conversion of results gives Q ranging from 2,160 gpm (136. lps) to 514 gpm (32.4 lps).

<u>VERTICAL INFLOW (Section 8.1.2)</u>

$Q = KIA$ Darcy Equation

Q (gpd) is the discharge to the pit floor.

K (gpd/ft^2) is the hydraulic conductivity of the igneous complex and Vinini hornfels.

I (dimensionless) is the hydraulic gradient, head differential in feet divided by the distance in feet.

A (ft^2) is the cross-sectional area of the vertical right cylinder.

To convert Q (gpd) to Q (gpm) divide by 1440. To convert Q (gpm) to Q (lps) multiply by 0.0631.

<u>Calculation at 14.2 Years</u>

K ranges from 0.1 to 1. gpd/ft^2

I = (6000-5700 feet)/(5700-3800 feet) = 0.158. The elevation of the top of the Eastern Assemblage carbonates is presumed to be at 3800 feet and the hydraulic potential is estimated at elevation 6000 feet (1830 m) (Plate II).

$A = \ r^2$ where r is the radius of the pit floor at 5700 feet and is equal to 850 feet (Plate V).

Substitution in the Darcy Equation and conversion of results gives Q ranging from 25 gpm (1.6 lps) to 249 gpm (15.7 lps).

Calculation at 20. Years

K ranges from 0.1 to 1. gpd/ft^2.

I = (6000–5000 feet)/(5000–3800 feet) = 0.833.

A = r^2 where r is the radius of the pit floor at 5000 feet and is equal to 915 feet (Plate V).

Substitution in the Darcy equation and conversion of results gives Q ranging from 152 gpm (9.6 lps) to 1522 gpm (96.1 lps).

INFLOW FROM FAULT AND FRACTURE ZONES (Section 8.1.3)

Vertical Pervious Zone in Igneous and Hornfels Wall Rocks

$$Q = \frac{14.96\ s_o\ L}{\sqrt{\pi t}} \sqrt{0.1337\ TS}$$

Stallman Equation (Lohman, 1972, p.43)

Q (gpd) is the discharge to the pit face.

T (gpd/ft) is the transmissivity of the water-bearing unit and is equal to the hydraulic conductivity, K (gpd/ft^2), times the thickness of the water-bearing material, b (feet).

The drawdown at the pit face, s_o, is the distance from the original ground-water level, 6400 feet, and the top of the seepage face. The latter is presumed to be halfway between the pit floor and the original ground-water level.

The time in days after the instantaneous imposition of the line sink is t.

S is the storage coefficient which in this unconfined case can be spoken of as the specific yield.

L is the width of the vertical pervious zone.

To convert Q (gpd) to Q (gpm) divide by 1440. To convert Q (gpm) to Q (lps) multiply by 0.0631.

Calculation at 14.2 Years

T = 70,000 gpd/ft = 100 gpd/ft^2 x 700 feet (= 6400–5700 feet)

s_o = 350 feet (= 6400–6050 feet)

t = 5.8 years x 365 days per year = 2117 days

S = 0.05

L = 75 feet

Substitution in the Stallman equation and conversion of results gives a Q of 72 gpm (4.5 lps).

Calculation at 20. Years

T = 140,000 gpd/ft = 100 gpd/ft^2 x 1400 feet (= 6400–5000 feet)

s_o = 700 feet (= 6400–5700 feet)

t = 11.6 years x 365 days per year = 4234 days

S = 0.05

L = 75 feet

Substitution in the Stallman equation and conversion of results gives a Q of 145 gpm (9.2 lps).

Vertical Pervious Zone Connected to Underlying Eastern Assemblage Rocks

Q = KIA Darcy Equation

Q (gpd) is the discharge to the pit floor.

K (gpd/ft^2) is the hydraulic conductivity of the Mt. Hope Fault and similar features.

I (dimensionless) is the hydraulic gradient, head differential in feet divided by the distance in feet.

A (ft^2) is the cross-sectional area of the vertical column.

To convert Q (gpd) to Q (gpm) divide by 1440. To convert Q (gpm) to Q (lps) multiply by 0.0631.

Calculation at 14.2 Years

K = 100 gpd/ft^2.

I = (6000–5700 feet)/(5700–3800 feet) = 0.158. The elevation of the top of the Eastern Asemblage carbonates is presumed to be at 3800 feet (Plate II).

A = 127,500 ft^2 = 75 feet (width of water-bearing zone) x 1700 feet (diameter of pit floor at 5700 feet (Plate V)).

Substitution in the Darcy equation and conversion of results gives a Q of 1400 gpm (88.3 lps).

Calculation at 20. Years

K = 100 gpd/ft^2.

I = (6000-5000 feet)/(5000-3800 feet) = 0.833.

A = 137,250 ft^2 = 75 feet (width of water-bearing zone) x 1830 feet (diameter of pit floor at 5000 feet (Plate V)).

Substitution in the Darcy equation and conversion of results gives a Q of 7900 gpm (500 lps).

APPENDIX 4-H

CONVERSION FACTORS

and ABBREVIATIONS

CONVERSION FACTORS AND ABBREVIATIONS

LENGTH

1 mile (mi) = 1.61 kilometers (km)
1 foot (ft) = 0.305 meters (m)
1 inch (in) = 2.54 centimeters (cm)

WEIGHT

1 pound (lb) = 0.454 kilograms (kg)

AREA

1 acre (ac) = 0.405 hectares (ha)
1 square mile (mi^2) = 2.590 square kilometers (km^2)

FLOW

1 cubic foot per second (cfs) = 28.32 liters per second (lps)
1 cubic foot per second (cfs) = 0.02832 cubic meters per second (m^3/s)
1 cubic foot per second (cfs) = 448.8 gallons per minute (gpm)
1 gallon per minute (gpm) = 0.0631 liters per second (lps)
1 acre-foot per year (AF/yr) = 0.620 gallons per minute (gpm)

VOLUME

1 acre-foot (AF) = 1.23 x 10^{-3} cubic hectometers (hm^3)

HYDRAULIC CONDUCTIVITY (K)

1 gallon per day per square foot (gpd/ft^2) = 0.407 cubic meters per square meter per day (m^3/m^2d) or meters per day (m/d, more commonly used)

TRANSMISSIVITY (T)

1 gallon per day per foot (gpd/ft) = 0.0124 cubic meter per meter per day (m^3/md) or square meters per day (m^2/d, more commonly used)

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